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THE UNIVERSITY OF ALBERTA

THE EFFECTS OF SHROUDING, SPRAY CHILLING AND VACUUM-PACKAGED AGING TIME ON THE PROCESSING AND EATING QUALITY ATTRIBUTES OF BEEF

BY

LAUREN MAI LEE

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

IN

FOODS

DEPARTMENT OF FOODS AND NUTRITION

EDMONTON, ALBERTA

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **"Effects of shrouding, spray chilling and vacuum-packaged aging time on the processing and eating quality attributes of beef"** in partial fulfilment of the requirements for the degree of Master of Science in Foods.

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ABSTRACT

The effects of shrouding, spray chilling and postmortem vacuum-packaged aging time on the processing and eating quality attributes of beef were determined by subjective and objective measurements.

Shrouding resulted in a slight reduction in the shrinkage of beef sides after 24 h of chilling. Percent fat and pH values of semitendinosus (ST) muscles were unaffected by shrouding method, but ST muscles from shrouded sides had a lower percentage of moisture than comparable muscles from unshrouded sides. Panelists rated cooked roasts from unshrouded sides to have a smaller amount of and softer connective tissue than roasts from shrouded sides. Other sensory and objective data for cooked ST roasts were generally not influenced by shrouding method.

Spray chilling effectively decreased muscle temperature and carcass shrinkage in beef sides. Hunter colour measurements of raw roasts showed some differences attributable to chilling treatment; however, chilling method did not affect colour data for the cooked roasts. The flavour of cooked ST roasts from conventionally chilled sides was scored as more intense than that of comparable roasts from spray chilled sides. Results for the other subjective and objective measurements showed no differences in cooked roasts due to chilling method.

Data for shroud by chill interactions showed that spray chilling of shrouded and unshrouded sides was most effective in lowering muscle temperature after 8 h of cooling. Shrouding and spray chilling were each effective in reducing carcass shrinkage; however, in combination, unshrouded spray chilled sides had the least amount of shrinkage at 24 h.

Vacuum-packaged aging time significantly increased percent drip in aging losses of ST roasts, although percent cooking losses were unaffected by aging time. Softness and tenderness scores combined with shear data suggested that more than 10 d of vacuum-packaged aging may be required for tender cooked beef.

Results of this study indicate that unshrouded sides may be spray chilled to maximize carcass chilling yields and cost efficiency in production. Shrouding and spray chilling did not adversely affect the eating quality of beef ST roasts. Trained panelists scored vacuum-packaged ST roasts aged for more than 10 d to be of desirable tenderness and palatability.

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1 INTRODUCTION

The Canadian meat industry is constantly concerned with the maximization of carcass chilling yields, cost efficiency in production and distribution, and the provision of palatable meat for consumption. Therefore, it is essential that traditional, newly adopted and potential meat processing procedures within the industry be reviewed. Practices currently of importance to the Canadian beef industry which require investigation include the shrouding and spray chilling of beef sides and vacuum-packaged, postmortem aging of beef roasts.

Traditionally, beef carcasses or sides have been covered in a cotton shroud as a method of improving carcass appearance. Recently, the necessity of this practice has been questioned due to the high costs involved in applying, removing and maintaining the shrouding material (Jones and Robertson, 1988a). Jones and Robertson (1988a and 1988b) conducted a series of experiments on the effects of shrouding on the appearance, shrinkage and muscle quality of spray chilled beef sides. Their (Jones and Robertson, 1988a and 1988b) results showed some beneficial effects of shrouding the beef sides; however, the significance of the benefits in relation to the economic impact of applying, removing and maintaining the shrouding material was questioned. No published information regarding the effects of shrouding on the eating quality of beef has been reported.

In order to minimize carcass shrinkage and increase carcass chilling rates, the Canadian beef industry has recently begun to implement the spray chilling of beef sides during cooling. Studies (Allen et al., 1987; Jones and Robertson, 1988b) have shown spray chilling to be more effective than conventional air chilling in reducing beef carcass shrinkage. Although some positive effects of spray chilling have been claimed (Allen et al., 1987; Jones and Robertson, 1988b), no investigations of the effects of spray chilling on the eating quality of beef have been published. Therefore, research concerning the palatability attributes of spray chilled beef is warranted.

The quality of spray chilled beef may be further influenced by vacuum-packaging. An increasing volume of beef processed in Canada is vacuum-packaged and boxed prior to distribution. Moreover, many retail chains are currently merchandising beef in vacuum-packaging. The period of time in which the beef is held in vacuum-packaging may vary from a few days to several weeks, depending on the time required for distribution and retail sale. No studies have investigated the combined effects of spray chilling and vacuum-packaged aging time on beef palatability. Information on the quality of spray chilled beef stored for varying periods of time is lacking. In addition, no published studies have examined the combined effects of shrouding, chilling method and vacuum-packaged aging time on the sensory attributes of beef.

Therefore, the objective of this project was to evaluate the eating quality of beef roasts subjected to the combined treatments of shrouding, spray chilling and varying lengths of postmortem vacuum-packaged aging. Beef quality evaluations were conducted using sensory and objective measurements.

2 LITERATURE REVIEW

Shrouding

The traditional practice of shrouding beef carcasses or sides is still widely used throughout Canada (Jones and Robertson, 1988a). The process of applying the shrouding material has been described (Miller, 1951; American Meat Institute, 1956). Prior to entering the cooler, the carcass or side is covered with a warm, damp sheet of heavy muslin. The shroud is stretched tightly around the carcass and held in place with pins. After chilling, the shroud is removed and the resultant carcass or side generally appears smooth and bleached. The shrouding material is washed and sterilized with a solution of sodium hypochlorite which tends to whiten the carcass surface fat.

Documentation on the conventional practice of shrouding beef carcasses or sides is limited in the scientific literature. There is little scientific information regarding the effect of shrouding on beef carcass characteristics or beef eating quality. Some researchers, although not studying shrouding as their primary objective, have reflected upon the potential purposes of shrouding. Swatland (1984) suggested that the main reason for shrouding was to allow the subcutaneous fat layer covering the carcass to appear smooth following cooling. Johnson et al. (1988) stated that shrouding was once a popular method to reduce weight loss in carcasses due to evaporation during overnight chilling. They

(Johnson et al., 1988) commented that spray chilling was the current method of interest for decreasing carcass shrinkage.

Two recent studies (Jones and Robertson, 1988a and 1988b) have investigated the effects of shrouding on the appearance, shrinkage and muscle quality of spray chilled beef sides. Jones and Robertson (1988a and 1988b) stated that the carcasses being produced in Canada are lean; thus, the necessity of shrouding carcasses for smoothening carcass fat (Swatland, 1984) may be questioned. Moreover, the appearance of a smooth carcass fat cover may not be crucial since a large quantity of beef is portioned into primal and subprimal cuts and boxed prior to distribution. In their (Jones and Robertson, 1988a) study, shrouded beef sides had a smoother layer of external fat cover than comparable unshrouded sides. No differences in marbling scores, pH at 24 h, area and colour of the loin muscle were evident between shrouded and unshrouded beef sides. Thus, Jones and Robertson (1988a) concluded that the beneficial effects of shrouding beef sides under water spray treatment were only minimal compared to the costs involved in applying, removing and maintaining the shrouds. Subsequently, Jones and Robertson (1988b) investigated shrinkage losses in shrouded and unshrouded beef sides, under spray or conventional chilling conditions. Although the data were not statistically analyzed, the researchers (Jones and Robertson, 1988b) observed a trend for spray chilled, shrouded sides to have greater carcass

shrinkage than the unshrouded counterparts. These sides were covered in a cotton shroud and subjected to an 8 h water spray treatment, after which the shrouds were removed. The sides were held in the cooler for an additional 16 h and then reweighed. Under conventional chilling conditions (identical cooler conditions with no water spray treatment), unshrouded sides showed greater shrinkage losses than shrouded sides. Concerning meat quality, Jones and Robertson (1988b) observed both shrouded and unshrouded, spray chilled sides to have similar meat colour and amount of fat thickness. Meat colour, shear values and fat thickness for shrouded and unshrouded conventionally chilled sides also did not differ (Jones and Robertson, 1988b). However, the fat on unshrouded, spray chilled sides had lower luminosity (Y) colour values (less white) than the fat on shrouded, spray chilled sides. In addition, the fat colour luminosity (Y) values for unshrouded, conventionally chilled sides were lower than those for unshrouded, spray chilled sides (Jones and Robertson, 1988b).

Cross et al. (1979) studied the effects of electrical stimulation and shrouding on the quality and palatability of beef carcasses. They proposed that a polyvinyl chloride (PVC) film overwrap, in addition to the conventional cloth shroud covering the carcass, would provide some insulation; and thus, retard the rate of chilling in muscles on the outside of the carcass. However, the PVC film had only minor effects on beef carcass quality compared to the significant effects of

electrical stimulation in decreasing the appearance of heat-ring and in improving muscle lean colour, texture and tenderness (Cross et al., 1979).

Limited research regarding the efficacy of shrouding carcasses or sides on the resultant quality of meat has been published. Moreover, no studies reporting the effects of shrouding on the palatability attributes of meat have been found; thus, research in this area is needed.

Spray chilling

Under conventional practices, the dressed animal carcass is moved to chilling coolers within approximately 1 h (Jensen, 1949). Generally, the conditions in the cooler provide air temperatures only slightly above the freezing point (Jensen, 1949; Miller, 1951; Frazier and Westhoff, 1988) and relative humidities within the range of 85 - 95% (Jensen, 1949; Wilson, 1981). Prompt, quick chilling of the carcass at low temperatures is imperative to prevent the growth of microorganisms (Miller, 1951; American Meat Institute, 1956; Smulders and Eikelenboom, 1987; Frazier and Westhoff, 1988). Controlled conditions for humidity are crucial. Low humidity levels increase carcass shrink and hasten discoloration and desiccation (Jensen, 1949); high humidity may increase carcass microbial growth (Jensen, 1949; Wilson, 1981). Carcasses are chilled to an internal temperature below 7°C (Miller, 1951;

Smulders and Eikelenboom, 1987) in approximately 24 h (Glover et al., 1977).

Current research on carcass chilling procedures has several objectives: (1) to reduce evaporative weight loss during chilling, (2) to accelerate the processing of carcasses to meat and (3) to achieve desirable tenderness (Taylor, 1987). Researchers are investigating immersion chilling, blast chilling and spray chilling as methods of optimizing the quality of meat in relation to chilling. Although spray chilling has been recently adopted by most North American slaughtering plants (Allen et al., 1987; Jones, 1988), only a few studies on spray chilled carcasses have been published.

During spray chilling, chilled water is intermittently sprayed on the surface of the carcasses during the initial hours of postmortem cooling (Allen et al., 1987; Greer and Dilts, 1988). This procedure minimizes evaporative losses and tissue shrinkage during chilling (Allen et al., 1987; Johnson et al., 1988; Jones and Robertson, 1988a). Carcass weight losses for beef chilled for 24 h in a North American conventional chilling system have been reported as 2.5% (American Meat Institute, 1956), 0.75 - 2.0% (Kastner, 1981), 1.4% (Allen et al., 1987) and approximately 2% (Powell and Griffiths, 1988). Beef carcass shrinkage may be attributed to desiccation and microbial spoilage during chilling (Hamby et al., 1987). The evaporative losses represent a significant

financial concern (Hamby et al., 1987; Greer and Dilts, 1988; Jones et al., 1988).

Various methods of spray chilling beef carcasses have been described. The spray water temperature has not been standardized. Water temperatures of 1°C (Johnson et al., 1988), 3°C (Allen et al., 1987), 5°C (Jones and Robertson, 1988a) and 12°C (Jones and Robertson, 1988b) have been used. Jones (1988) commented that the effects of spray water temperature on the quality of beef must be examined, as cold shortening may be induced in the carcass if pre-chilled water (1°C) is used without prior electrical stimulation of the carcass. The length and frequency of the spray chilling cycles has varied from 60 sec cycles every 15 min (Allen et al., 1987) to 60 sec cycles every 8 min (Johnson et al., 1988). Total spray chilling periods varied from 3 - 12 h, depending on the objectives of the study. However, intermittent spray chilling periods of 3 - 8 h are typical in commercial beef slaughtering plants (Johnson et al., 1988). Following spray chilling, carcasses are chilled under conventional conditions for 20 - 24 h postmortem.

Investigations of the effects of spray chilling on beef carcasses focus primarily on carcass shrinkage and muscle quality. Allen et al. (1987) reported that beef sides spray chilled for 8 h lost 1.14% less weight than comparable conventionally chilled sides. Johnson et al. (1988) compared different lengths of spray chilling periods on beef carcass

shrinkage and found that 3 h spray chilling periods reduced carcass shrink by 0.7%, whereas 6 h periods resulted in an overall weight gain. Jones and Robertson (1988a and 1988b) investigated the effects of shrouding and spray chilling on the shrinkage and quality of beef carcasses. Carcass shrinkage for unshrouded, spray chilled sides was significantly lower than that for shrouded, spray chilled sides (Jones and Robertson, 1988a and 1988b). Spraying sides for 4, 8 or 12 h reduced carcass shrinkage measured at the end of the 24 h chilling period; however, after 6 d of chilling under conventional conditions, only the 12 h spray chilled sides had less shrinkage than the conventionally chilled controls.

For muscle quality, spray chilling had no significant effect on lean muscle colour of beef (Allen et al., 1987; Jones and Robertson, 1988a). Furthermore, Allen et al. (1987) and Jones and Robertson (1988a) found no change in fat thickness on beef sides due to spray chilling. Moisture content analysis showed that the adipose tissue of spray chilled beef sides was more moist than that of conventionally chilled sides (Johnson et al., 1988). Also, Johnson et al. (1988) found that following spray chilling, the trim Holstein steer carcasses appeared wet and had a less attractive appearance than carcasses higher in fat. Jones and Robertson (1988a) reported that the fat on beef carcasses, spray chilled for 8 h or more, had significantly higher luminosity (Y)

values (more white) than the fat on conventionally chilled control sides. Shear values for cooked beef were not affected by spray chilling (Jones and Robertson, 1988b).

Studies (Greer and Dilts, 1988; Jones et al., 1988) on pork processing have used identical spray chilling procedures. The pork carcasses were spray chilled, with 5°C water for 60 sec cycles every 15 min for a 10 h period, and then conventionally chilled at 1° C for 14 h. Jones et al. (1988) showed that spray chilled pork carcasses had significantly less carcass shrinkage than conventionally chilled sides after 24 h. Spray chilled pork carcasses had higher levels of subcutaneous fat than their conventionally chilled counterparts (Jones et al., 1988). Jones et al. (1988) reasoned that spray chilling reduced the weight loss in the fat component primarily, and not in the carcass lean. Regarding shear values of cooked pork, meat from spray chilled pork carcasses had higher shear values than that from conventionally chilled pork carcasses (Jones et al., 1988), but the researchers doubted that this was due to cold shortening since the spray chilling procedure only marginally increased the rate of chill.

Cold shortening is the phenomenon whereby muscle fibers contract to a fraction of their original length upon exposure to extremely cold conditions or to an uneven application of cold temperatures (Cliplef and Strain, 1976). Cold shortening is dependent on the rate at which muscle temperature is

lowered after slaughter (Bowling et al., 1987), and is likely to occur when prerigor muscle is cooled to 10°C in less than 10 h (Dransfield and Jones, 1978). Greer and Dilts (1988) monitored carcass temperatures during the spray chilling of pork carcasses. The surface temperatures of the spray chilled pork carcasses were 1.5°C lower at 4 h, and 0.9°C lower at 10 h than comparable surface temperatures of conventionally chilled carcasses taken at the same time (Greer and Dilts, 1988).

Due to the increased water activity on the carcass surface in spray chill systems, the bacteriological consequences must be addressed. Acetic and lactic acid decontamination systems have been compared with conventional chilling and water spray chilling for their effects on the microbiological and sensory properties of beef (Hamby et al., 1987). Intermittent sprays of acetic or lactic acid significantly reduced aerobic plate counts when compared to the conventionally chilled controls (Hamby et al., 1987). However, in comparing the aerobic plate counts for water spray chilled beef sides with conventionally chilled controls, no significant differences were found (Hamby et al., 1987). The boneless rib and clod subprimal cuts obtained from water sprayed beef carcasses had poorer off-odor scores than the same cuts from conventionally chilled controls (Hamby et al., 1987). Carcasses sprayed with acetic acid had a strong acetic acid odor (Hamby et al., 1987). Greer and Dilts (1988) demonstrated that mesophilic bacterial numbers on spray

chilled pork carcasses were not changed after chilling, although conventional chilling significantly reduced the number of mesophiles.

Information on the spray chilling of beef sides is limited. Studies to date have reported a reduction in carcass shrinkage with the use of water sprays; the effects of spray chilling on carcass appearance and muscle quality are varied. Research on the standardization of spray chilling procedures is needed. Moreover, studies investigating the palatability attributes of spray chilled beef are lacking. Thus, research concerning the effects of spray chilling on the eating quality of beef is warranted.

Vacuum-packaged postmortem aging

Numerous studies have examined the tenderization effects of prolonged storage (aging) of beef at temperatures above its freezing point (Davey and Gilbert, 1967; Davey and Dickson, 1970; Bouton and Harris, 1972b; Minks and Stringer, 1972; Smith et al., 1978). Aging has been associated with changes in the structural components of myofibrils and with alterations in myofibrillar protein composition (Davey and Dickson, 1970; Smith et al., 1978; Swatland, 1982; Lanari et al., 1987). Conventional methods of aging beef involve storing the meat at -1°C to 5°C for periods of time, ranging from three days to three or four weeks (Minks and Stringer, 1972). Differences in optimal aging times for conventionally

processed beef have been reported. Jeremiah and Martin (1978), in reviewing the literature, noted researchers' findings that aging beef for 6 d at 2°C (Martin et al., 1971) or for more than 11 d at 2°C (Culp et al., 1973) would provide acceptable beef tenderness. Additionally, Lanari et al. (1987) reported several recommendations in the literature: 10 - 14 d at 5°C (Stanley, 1976); 14 d at 2 - 4°C (Dransfield et al., 1980) and 7 d at 1°C (George et al., 1980).

In 1967, dramatic changes in beef processing, distribution and retail fabrication occurred with the introduction of "boxed beef" (Cole, 1986). Centralized processing, which involves the vacuum-packaging of primal and subprimal cuts of beef, allows for improved sanitation and reduced evaporative losses compared to conventional whole carcass distribution (Minks and Stringer, 1972; Hodges et al., 1974; Cole, 1986). The vacuum-packaged boxed beef is transported to retail outlets where the primal and subprimal pieces of meat are fabricated into retail cuts. This concept of boxed beef would not have developed without the technology of vacuum-packaging. The meat is placed into an oxygen impermeable bag or pouch (Breidenstein, 1982), subjected to vacuumizing equipment for removal of air and sealed to prevent further contact of the meat with oxygen (Taylor, 1982). The tenderization effects of aging continue to occur in meat held in vacuum-packaging (Minks and Stringer, 1972; Hodges et al., 1974; Lanari et al., 1987). In vacuum-packaging, the shelf

life of meat may be extended to 21 - 28 d (Young et al., 1988) or as long as 7 weeks (Carpenter et al., 1975) and 10 weeks (Joseph, 1976). For tenderness, the optimal aging time for vacuum-packaged beef has been reported as 7 d (Joseph, 1976), 10 d (Swatland, 1982), 11 d (Smith et al., 1978) and 14 d (Hodges et al., 1974).

Vacuum-packaging also affects the colour of the meat. Metmyoglobin, characteristically brown in colour, is formed from red oxymyoglobin after the exclusion of oxygen during vacuum-packaging (Pierson et al., 1970; Young et al., 1988). As the residual oxygen is utilized by muscle respiration of microbial organisms, metmyoglobin is converted to myoglobin, which is purplish in colour (Pirko and Ayres, 1957; Cole, 1988). Cole (1988) stated that the characteristic purple colour of vacuum-packaged meat is evident approximately 8 h after packaging.

Various findings on the palatability of vacuum-packaged meat have been reported. Minks and Stringer (1972) noted that aging beef in vacuum-packaging for 7 d had no significant effect on beef flavour and juiciness. Hodges et al. (1974) aged beef in vacuum-packaging for up to 28 d, and found an increase in off-flavours as the storage time was extended; however, the change in flavour in most beef samples was not detected until after 7 d of storage.

Another factor of interest is the reduced weight loss from evaporation during storage of vacuum-packaged meat

(Breidenstein, 1982). Breidenstein (1982) suggested that the low evaporative losses may be attributed to the low moisture-vapour transmission rate of the film used in making the vacuum-packaging bags and pouches. Minks and Stringer (1972) and Hodges et al. (1974) found negligible weight losses for beef aged in vacuum-packaging. Although evaporative losses have not been a problem in vacuum-packaged meat, meat shrinkage has been reported. The shrinkage factor has been associated with purge or drip losses (Hodges et al., 1974), which appear as the unattractive bloody exudate often found in vacuum-packaged beef (Breidenstein, 1982). Breidenstein (1982) listed several ante- and postmortem factors which may influence purge losses: age and breed of cattle, feeding conditions, rate of postmortem chilling, degree of vacuum in the package and rigidity of the packaging material. Generally, purge losses less than 2% are considered to be acceptable by the meat industry (Breidenstein, 1982; Neel et al., 1987).

Allen et al. (1987) monitored purge losses of vacuum-packaged ribs and inside rounds from conventionally and spray chilled beef sides. After 15 d of vacuum-packaged aging at 2°C, inside rounds from spray chilled sides had significantly greater purge than comparable vacuum-packaged inside rounds from conventionally chilled sides (Allen et al., 1987). Also, primal ribs from spray chilled sides had higher purge losses than ribs obtained from conventionally chilled sides, but the

differences were not significant. Allen et al. (1987) proposed that the differences in purge losses between the two cuts may have been due to the position of the primals on the beef sides.

Jones and Robertson (1988b) also subjected ribs and inside rounds from conventionally and spray chilled beef sides to vacuum-packaged aging, but for a shorter period than Allen et al. (1987). After aging for 6 d at 2°C, the purge losses for vacuum-packaged beef cuts obtained from spray chilled sides did not differ significantly from those for cuts from conventionally chilled sides. Purge losses for subprimal beef cuts from sides sprayed with water or organic acids were greater than those of controls, after 28 d of vacuum-packaged aging at 2°C; however, only a few of these comparisons were statistically significant (Hamby et al., 1987). Results from these studies (Allen et al., 1987; Hamby et al., 1987; Jones and Robertson, 1988b) suggest that purge losses for vacuum-packaged beef from spray chilled sides are not of significant concern, as all purge values reported were not excessively high.

Aside from the effects of vacuum-packaged aging time on meat tenderness, other consequences must be considered. Breidenstein (1982) noted that the lag phase in bacterial growth of vacuum-packaged meat was longer than the lag phase in comparable meat not vacuum-packaged. However, as the storage time for vacuum-packaged beef increased, bacterial

growth on the meat was enhanced (Hodges et al., 1974; Seideman et al., 1976).

Although the effects of aging beef in vacuum-packaging have been investigated, only a few researchers have examined the aging of spray chilled beef. In those few studies (Allen et al., 1987; Hamby et al., 1987; Greer and Dilts, 1988; Jones and Robertson, 1988b), several factors have been addressed, including raw meat quality, purge losses and microbiological concerns; however, no studies have examined beef palatability. Thus, research on the eating quality of spray chilled beef held in vacuum-packaging for various periods of time is needed.

Sensory evaluation of meat quality

Sensory evaluation methods for the descriptive assessment of meat quality have been defined (AMSA, 1978; Cross et al., 1978 and 1986). Sensory evaluation is the ultimate method of determining quality attributes of meat, especially tenderness (Alexander, 1976; Larmond, 1976). A highly trained sensory panel may perform analytical tests to evaluate meat samples for differences and similarities, and to identify and quantify specific sensory characteristics (IFT, 1981). The AMSA (1978) and Cross et al. (1978 and 1986) have outlined a method for the selection, training and evaluation of a descriptive sensory panel for meat. The method consists of four steps: personal interview, screening, training and performance

evaluation. The purpose of the interview is to establish each potential panelist's interest and availability for participation in sensory analysis. The screening process serves as a method of quickly eliminating candidates who are unable to detect large differences in sensory characteristics. In the training step, the panelist is prepared to become precise and consistent in making sensory judgements. Cross et al. (1978) stated three purposes in training a meat panel: (1) to familiarize the panelist with test procedures, (2) to improve the panelist's ability to recognize and identify sensory characteristics, and (3) to improve the panelist's sensitivity to and memory for sensory test attributes. According to the procedures of Cross et al. (1978), panelists were trained to identify differences in tenderness, juiciness and connective tissue, the three most predominant characteristics of interest in meat research. Panel performance evaluations were conducted to help the panel leader determine problems which individual panelists may be experiencing, so that subsequent training sessions could be planned to address any difficulties. Final evaluation results were used to select a minimum of eight panelists for a trained descriptive panel (AMSA, 1978; Cross et al., 1978 and 1986).

Effective sensory evaluation requires a physically controlled environment (Larmond, 1973). Larmond (1973) described the optimal setting which would not bias any sensory judgements. A quiet, comfortable, odor-free testing facility,

where panelists are allowed to make independent judgements in separated booths is recommended (ASTM, 1968). The temperature and humidity of the area must be controlled, and the lighting must be uniform, adequate and adjustable (Larmond, 1973; Cross et al., 1986). Special lighting conditions, such as red fluorescent tubes may sometimes be used to mask colour distractions in a given sample; however natural lighting is suitable for the majority of meat samples for sensory evaluation (Cross et al., 1986).

Guidelines for meat sample preparation and presentation were provided by the AMSA (1978) and Cross et al. (1978 and 1986). The size and shape of the meat samples provided to panelists for evaluation vary among researchers. Some researchers recommend using 1.3 or 2.5 cm (in diam) cores, while other researchers use cubes or slices (AMSA, 1978). The temperature of the meat sample should adhere to common consumer practice (AMSA, 1978), and uniformity in sample temperature during testing was stressed (Caporaso, 1978). The technique devised by Caporaso (1978) consisting of a double boiler system for heating beef cores to 50°C, has been used by some researchers (Shand et al., 1984; Paterson et al., 1988). The number of samples to be evaluated during one session depends upon several factors: ease of fatigue of the panelists, pleasantness of samples to be tested and the number of attributes to be evaluated (AMSA, 1978). The AMSA (1978) generally recommended testing of six samples as a maximum for

trained panelists if six or seven attributes per sample were being evaluated. In previous studies (Hawrysh et al., 1975; Hawrysh et al., 1985; Seideman and Theer, 1986; Bohnenkamp and Berry, 1987), trained panelists have evaluated more than six samples of beef during each panel session without experiencing fatigue or problems in discriminating differences between samples. Additionally, no fewer than two portions of the same sample should be provided to the panelist for evaluation of all required attributes (Cross et al., 1986). Concerning the order of sample presentation, each panelist should receive coded samples in different randomized orders (AMSA, 1978).

Category scaling is the most routinely used technique for the descriptive assessment of meat (AMSA, 1978). This technique utilizes a graduated scale, usually seven to nine categories in length for the intensity of a given attribute (Shand et al., 1984). Shand et al. (1984), in reviewing the literature, stated that most meat scientists conducting sensory tests employ an eight-point scale. The AMSA (1978) has listed the descriptors commonly used on a typical eight-point scale for several sensory attributes. The common attributes evaluated in meat samples include tenderness, juiciness and flavour.

Tenderness is the most important textural property of meat (Szczesniak and Torgeson, 1965; Alexander, 1976). Trained panelists may evaluate meat tenderness by describing factors such as the amount of detectable connective tissue,

ease of fragmentation and overall tenderness (Cross et al., 1986). In addition, Cover et al. (1962b) listed other components of tenderness as softness to tongue, cheek and tooth pressure, mealiness and amount/firmness of connective tissue. Tenderness may also be based upon the number of chews required to masticate the sample (Paul, 1962). Harrington and Pearson (1962) found great variations in individual chew counts on similar samples, but commented that the method of counting enabled the panelist to concentrate on the tenderness attribute, with temporary exclusion of other sensory characteristics.

Juiciness evaluations are based upon the initial and final release of juices in the meat sample (Cross et al., 1986). Alexander (1976) described the first parameter as "initial juiciness", and the second as "juiciness". Alexander (1976) referred to the term "juiciness" as the amount of juiciness present after a fixed degree of mastication. Juiciness is influenced by the flavour and texture of meat, and can be directly related to its fat and moisture content (Cross et al., 1986).

Descriptive sensory methods may utilize sensory panelists to describe flavour characteristics of a meat sample, by indicating its intensity value (Cross et al., 1986). A sensory panel can be trained to identify specific flavour notes, such as rancid or aged (AMSA, 1978). Detailed, sophisticated flavour evaluation is more appropriately

evaluated using "flavour profile analyses" or "quantitative descriptive analyses" (AMSA, 1978).

Sensory methods are the most desirable means for evaluating the eating quality of meat since palatability is a human sensation (Alexander, 1976). In addition, instrumental objective devices may be used to supplement subjective procedures (Cross et al., 1986).

Trained panel assessments of the eating quality of spray chilled, vacuum-packaged beef aged for various periods of time are nonexistent. Research in this area is crucial because palatability ultimately determines the eating quality and acceptance of all meat.

Objective measurements of meat quality

Various instrumental techniques may be used to assess the textural properties of meat, although no ideal objective method has been established to predict meat tenderness (Harris, 1976). Objective measurements useful for assessing meat texture/tenderness have been extensively reviewed (Szczesniak and Torgeson, 1965; Harris, 1976; Stanley and Swatland, 1976; Berry, 1983).

The most widely used objective method for evaluating meat tenderness is the Warner-Bratzler shear (Harris, 1976; Stanley and Swatland, 1976; Moller, 1981; Moller et al., 1981; Moller et al., 1982; Cross et al., 1986; Seideman and Theer, 1986; Lanari et al., 1987). This shear method involves applying a

force via a vee-shaped blunt edged blade and measuring the amount of force required to shear the meat sample (Harris, 1976; Moller et al., 1981). An Instron Universal Testing machine equipped with a Warner-Bratzler shear attachment and load cell can measure cohesion and elasticity (Cross et al., 1986; Seideman and Theer, 1986). Peak force values have been reported to more closely relate to the myofibrillar component of toughness, rather than to the connective tissue component (Bouton and Harris, 1972a; Cross et al., 1973). Penetrometer readings have also been used to evaluate meat softness (Paul et al., 1970).

Objective methods to assess meat juiciness are related to water-holding capacity. The press technique is the standard method used to determine the water-holding capacity of meat (Tsai and Ockerman, 1981). The basic procedure, as described by Stanley and Swatland (1976) and Cross et al. (1986), determines the amount of free water present in a meat sample with the use of a Carver Laboratory Press.

Meat colour can be described by characteristics such as hue, value and chroma, where hue refers to the actual colour, value describes the lightness or darkness of meat colour and chroma pertains to the intensity of colour (Cross et al., 1986). Instruments used to measure colour duplicate the known wavelength response characteristics of the colour receptors in the human eye (Hunter, 1987). Two common measurable colour attributes are the 'L, a and b' and C.I.E. tristimulus

measurements (Hunter, 1987). The 'L, a and b' opponent-colours measurement describes the darkness-lightness (L), redness-greenness (a) and yellowness-blueness (b) values of the sample (Hunter, 1987). The C.I.E. measurements expressed as 'X, Y and Z', 'x and y' or 'Y' are considered as a universal colour system (Hunter, 1987).

Correlations between instrumental and sensory measurements have been inconsistent. Szczesniak (1987) identified three key factors which affect sensory and instrumental correlations: (1) similarity of the physical aspects of the two sets of measurements, (2) nature of the test material (heterogeneity and rheological characteristics) and (3) selection of sensory terms and scales. Irrespective of the variability in reported correlations, instrumental measurements are used widely by researchers to supplement sensory data (Cross et al., 1986).

3 EXPERIMENTAL PROCEDURE

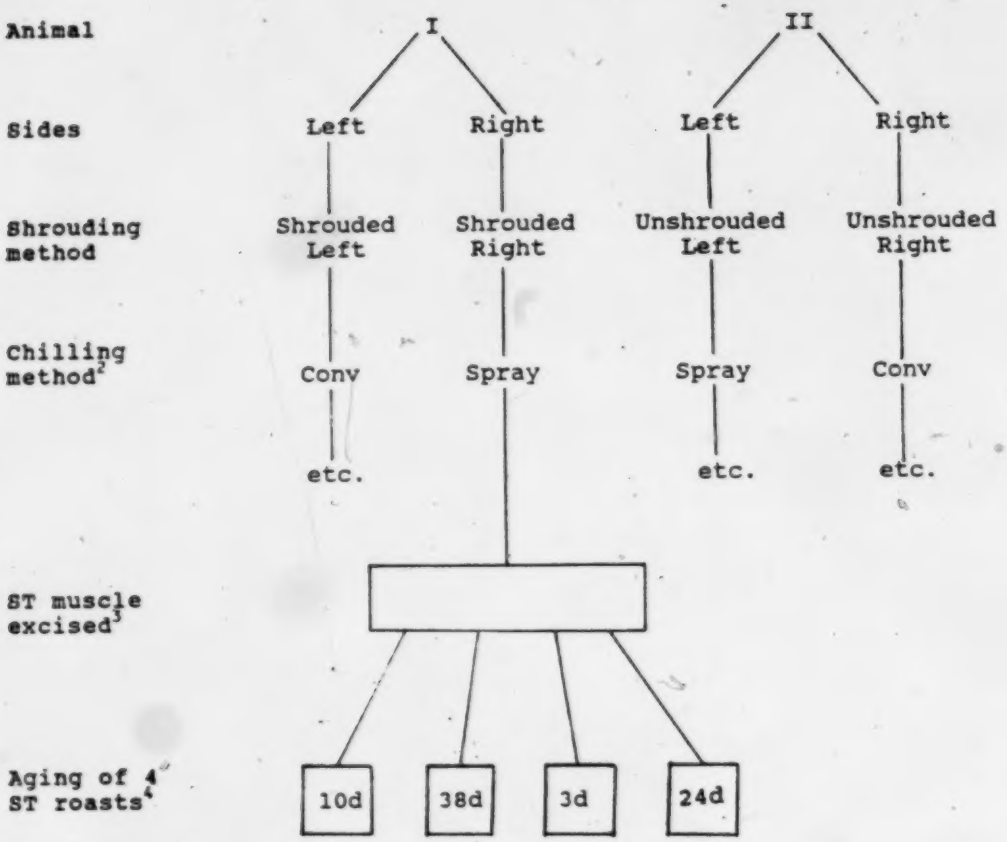
Experimental design and statistical analysis

Subjective and objective measurements were used to evaluate the quality attributes of semitendinosus (ST) roasts which were subjected to various processing treatments. The design for one experimental block is presented in Figure 1. A total of 16 animals were involved in the study. Following slaughter, paired beef sides were either shrouded or unshrouded. Subsequently, within a shroud treatment, the sides were randomly assigned to a chilling method (conventional or spray chilling). After chilling, the ST muscle from each side was excised and cut into four roasts. Each of the four ST roasts was assigned to one of four aging times.

To control the effects due to animal variation, the paired sides from one animal were allotted to one of the shrouding methods; however, for chilling, the left and right sides were designated to either the conventional or spray chilling method. Thus, one complete block in this experimental design consisted of two pairs of left and right sides: one pair of shrouded sides and one pair of unshrouded sides. The 16 animals involved in the study were randomly organized into eight blocks or replicates.

The four roasts, cut from each of the ST muscles, were assigned to the four aging periods (3, 10, 24 and 38 d) according to Latin square designs. Roasts from the shrouded

Figure 1. Design for one experimental block[1].



[1] Repeated 8 times; 16 animals in total.

[2] Sides were randomly assigned to a chilling method.
Conv = Conventionally chilled; Spray = Spray chilled.

[3] Semitendinosus (ST) muscle excised from side after chilling.

[4] ST roasts were assigned to postmortem, vacuum-packaged aging periods, using randomized Latin squares (see Figures 2 and 3, p.29-30).

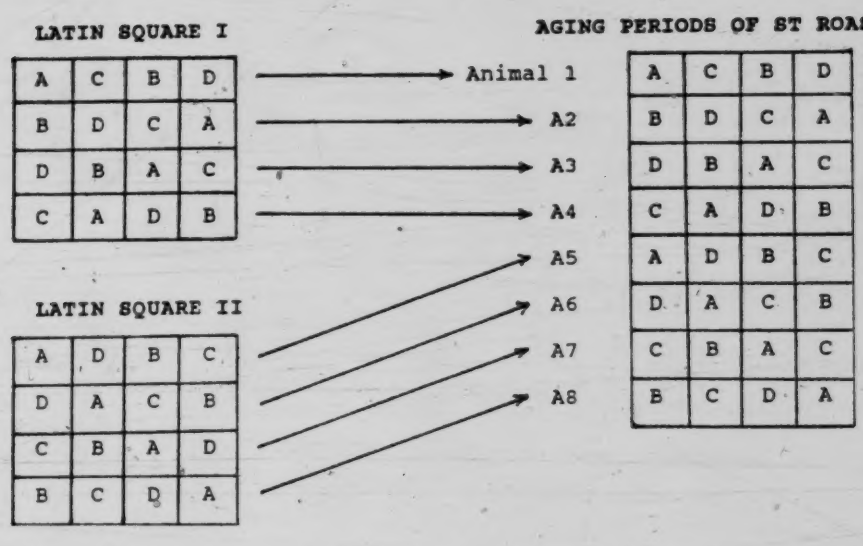
sides were distributed to aging periods using all eight rows from two (4 x 4) Latin squares, as illustrated in Figure 2. Roasts from paired muscles, excised from conventionally and spray chilled sides, were given the same row in the Latin square to minimize any possible anatomical differences within the muscle. Thus, roasts from the same anatomical location were aged for identical periods of time (Figure 3). Using two different Latin squares, similar procedures were followed for assigning roasts cut from the unshrouded carcass sides.

During one panel session, roasts representing all four aging periods from paired muscles (conventionally and spray chilled) were evaluated by trained sensory panelists. This design allowed for equal emphasis on chilling methods and postmortem aging periods during statistical analysis.

Data were analyzed using analyses of variance. Sources of variation consisted of shrouding methods (n=2), chilling methods (n=2) and postmortem aging times (n=4). Student-Newman-Keuls' Multiple Range test (SNK) was used to establish significant differences among treatment means (Steel and Torrie, 1980). For those treatment interactions which were significant, comparisons between the cell means were made using Fisher's Protected LSD statistical test (Steel and Torrie, 1980).

Correlation coefficients were calculated to identify relationships between appropriate sensory and objective data.

Figure 2. Allocation of the four aging periods to semitendinosus roasts for each of the shrouded sides[1].



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[1]The same procedure also applied to roasts from unshrouded sides.

A = 3 d aging period

B = 10 d aging period

C = 24 d aging period

D = 38 d aging period

Figure 3. Aging periods of the eight semitendinosus roasts (from shrouded sides subjected to conventional or spray chilling) evaluated during each panel session.

ST ROASTS FROM SHROUDED, CONVENTIONALLY CHILLED SIDES

		Anterior		Posterior	
P1	A1 (L)	3	24	10	38
P2	A2 (R)	10	38	24	3
P3	A3 (L)	38	10	3	24
P4	A4 (R)	24	3	38	10
P5	A5 (L)	3	38	10	24
P6	A6 (R)	38	3	24	10
P7	A7 (L)	24	10	3	38
P8	A8 (R)	10	24	38	3

ST ROASTS FROM SHROUDED, SPRAY CHILLED SIDES

	Anterior		Posterior	
A1 (R)	3	24	10	38
A2 (L)	10	38	24	3
A3 (R)	38	10	3	24
A4 (L)	24	3	38	10
A5 (R)	3	38	10	24
A6 (L)	38	3	24	10
A7 (R)	24	10	3	38
A8 (L)	10	24	38	3

P1 - P8 = Panel Session 1 - 8

A1 - A8 = Animal 1 - 8

(L) = Left ST muscle

(R) = Right ST muscle

3 = 3 d aging period

10 = 10 d aging period

24 = 24 d aging period

38 = 38 d aging period

Meat used for the study

Sixteen young steers (average age of 16 months) of similar breeding and feeding regimen, were used for the study. The animals were slaughtered in two groups at the Agriculture Canada Research Station in Lacombe, Alberta. The eight animals slaughtered first were those randomly designated to the unshrouded treatment. The remaining eight animals slaughtered were those randomly assigned to the shrouded treatment.

After slaughter, each carcass was washed, trimmed, split into left and right sides and weighed. Those sides assigned to the shrouded treatment were covered in a cotton shroud, while the other sides remained unshrouded. All sides were hung 15 - 20 cm apart in a cooler ($1^{\circ}\pm2^{\circ}C$), with the velocity of the air in the cooler maintained at 0.5 m/sec. Conventionally chilled sides were held in the cooler ($1^{\circ}\pm2^{\circ}C$) for a total period of 24 h. Sides assigned to the spray chilling treatment were intermittently sprayed (60 sec, every 15 min for a total of 8 h) with tap water ($10^{\circ}C$). Following spray chilling, the sides were weighed, and then conventionally air chilled for an additional 16 h. During the cooling of all sides, the temperatures of the longissimus (LD) and semimembranosus (SM) muscles were measured at 45 min, 4 h, 8 h and 24 h. Sides were reweighed and graded after chilling.

Whole semitendinosus (ST) muscles were excised from each side. Four adjacent roasts were cut perpendicular to the

longitudinal axis of the muscle fibers from each ST muscle, beginning at the anterior end. Each roast was weighed and analyzed for colour. Next, the roasts were labelled and individually vacuum-packaged in clear barrier bags (Cryovac™) using a Multivac™ system (Model AGI 1976). Packages were heat-shrunk using a Cryovac™ heat system (Model 6520A), with the water bath at 93°C.

Trimmings from the anterior and posterior ends of each muscle were combined, wrapped in aluminum foil and plastic, and frozen (-30°C). The trimmings were used to determine pH and some proximal analyses. The vacuum-packaged roasts, in closed cardboard cartons, were held in a walk-in cooler ($1^{\circ}\pm1^{\circ}C$) for the duration of their assigned aging period. After aging, each roast was unwrapped and weighed to determine drip loss. Colour was measured again to detect changes during aging. All roasts were individually repackaged and frozen (-30°C) in still air. The frozen roasts were transported in cardboard cartons to the University of Alberta and stored (approximately 30 days) at -30°C for later sensory and objective analyses.

Prior to cooking, each roast was completely thawed in its vacuum-packaging in the refrigerator ($3^{\circ}\pm1^{\circ}C$) for 24 h.

Objective measurements: Raw samples

Colour

The colour of both cut surfaces of each roast was measured using a Macbeth Color Measuring System (Model M2020 PL) by researchers at the Lacombe Meat Research Station. Lightness 'L', redness 'a' and yellowness 'b' values were recorded prior to and after vacuum-packaged aging.

Drip in aging

For each roast, the weight of drip present in the vacuum-packaging at the end of the aging period was determined. The weight of drip was expressed as a percentage, based on the weight of the raw roast prior to aging.

Drip in thaw

The weight of drip in thaw of each roast was calculated as a percentage, based on the weight of the roast after aging and prior to repackaging for frozen storage.

Fat and moisture

Prior to fat and moisture determinations, each thawed meat sample was coarsely ground in an electric meat grinder (Rival Grind-o-matic, Model C2100M/3) and freeze-dried in a Labconco freeze-dryer (Model Freeze Dry-12) for 24 h. The freeze-dried samples were reground in a Waring Commercial Blendor (Model 33BL73) on low speed for 30 sec. The

percentage of fat in each sample was determined using an ether extract procedure, based on Method 24.005 of the Association of Official Analytical Chemists (1980). Duplicate 2 g samples were refluxed with petroleum ether for 9 h using a Labconco Goldfisch extraction apparatus. Next, the ether was evaporated and the remaining extract was dried in a mechanical convection oven (Precision Scientific, Model 625) at 100°C for 30 min. The weight of the fat extract was determined.

For moisture determinations, Method 24.002 of the Association of Official Analytical Chemists (1980) was used. Duplicate 2 g samples were placed in lidded aluminum moisture dishes and dried for 24 h at 100°C.

The amounts of fat and moisture were calculated as percentages, based on the equivalent wet weight of the freeze-dried sample which was analyzed.

pH

A Fisher Allied Accu-pHast™ electrode connected to a Fisher Accumet pH meter (Model 915MP) was used to measure the pH of each raw ST muscle sample. A thawed 20.0 g sample from each roast was blended with 100 mL distilled water in a Waring Commercial Blendor™ (Model 33BL73) on low speed for 60 sec. The homogenate was filtered (Whatman, Qualitative 1 grade filter paper) into two portions for duplicate pH determinations.

Cooking procedure

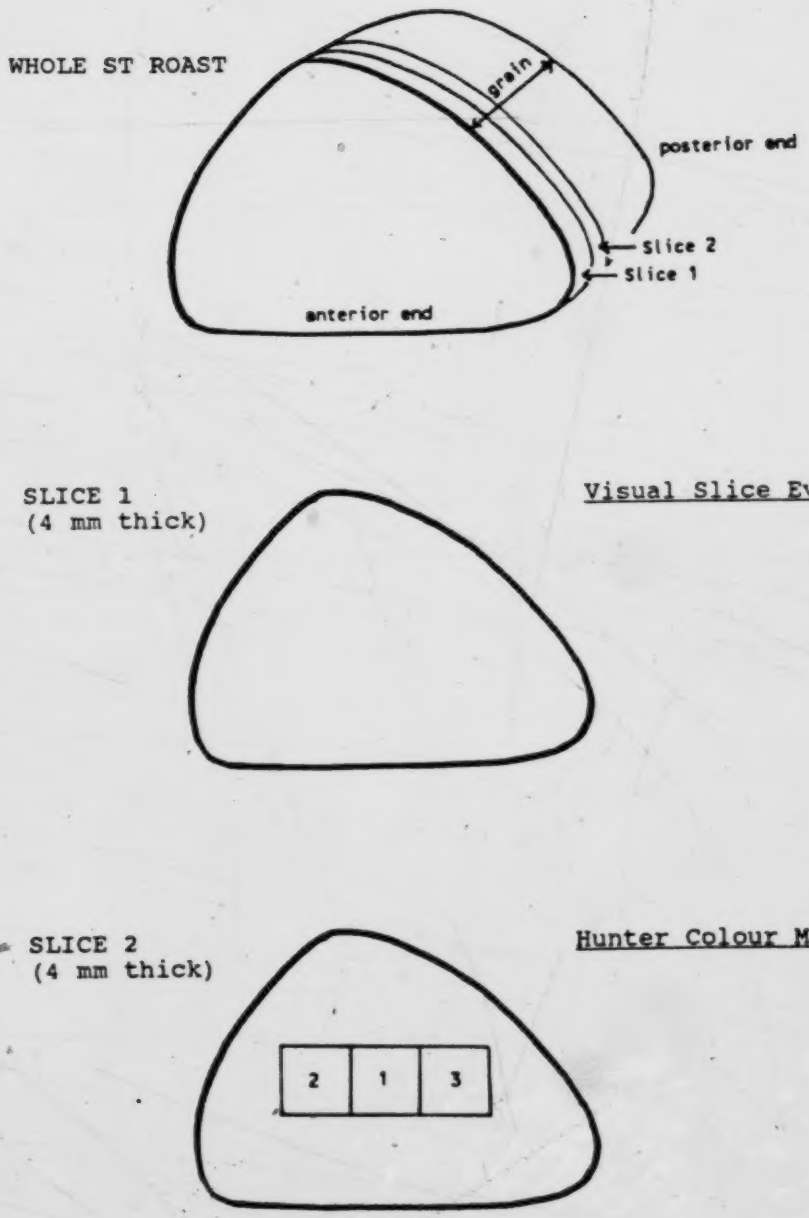
Each thawed roast was positioned anterior side up, on a roasting rack in an aluminum pan (25 cm in diam). Each roast was individually roasted to an internal temperature of 65°C in one of four identical household ovens (Kenmore, Model Mark 3), preheated to 163°C. The internal temperature of each roast was constantly monitored with two copper-constantan thermocouples connected to a Honeywell recording potentiometer (Electronik 15). Post-oven temperature rise was monitored while each roast was cooled. After cooling to 50°C (about 30 min), each roast was weighed, wrapped in impermeable plastic wrap (Saran™) and aluminum foil. Roasts were refrigerated (3°±1°C) until sensory and objective evaluation the following day.

Sampling procedure

The sampling procedure for subjective and objective tests (Figure 4) was standardized during preliminary work.

An electric meat slicer (Berkel, Model 1836) was used to section each refrigerated, cooked roast into uniform slices. First, a 4 mm slice, perpendicular to the grain, was taken from the anterior side of the roast for slice evaluation. The small size of the roast did not allow for the slice to be taken from the central region of the roast.

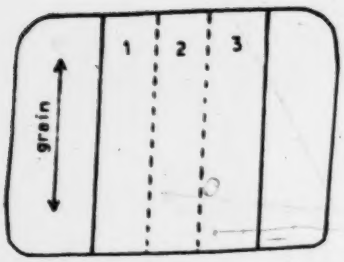
Figure 4. Sampling plan for slice and colour measurements of semitendinosus roasts.



Next, a 4 mm slice, perpendicular to the grain, was cut for colour measurements. Using a 2.5 cm^2 plastic template, a sample was removed from the center of this slice. Then, two other squares of meat were cut from the same slice and placed beneath the first square to give a stacked, 12 mm high sample appropriate for colour measurements (Figure 4). This sampling procedure was necessary due to the size of the roasts. During preliminary work, colour readings of samples prepared in this manner did not differ from those of single, 12 mm thick samples.

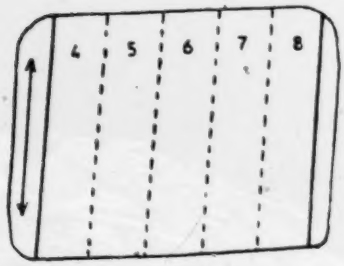
Four adjacent slices (each 1.3 cm thick), removed from the proximal side of the roast, were chosen for other objective and sensory measurements (Figure 5). The first slice was allocated to the penetrometer test, and the fourth slice was used for Warner-Bratzler shear determinations. For these tests, rectangular cores (1.3 cm x 1.3 cm x 4-5 cm) were cut parallel to the grain. The second and third slices were cut into similar sized cores for sensory samples and press fluid measurements. For the sensory samples, four adjacent cores nearest the center region were selected. Then, two cubes (1.3 cm^3) of beef were cut from each core, yielding a total of 16 cubes. Following the preparation of sensory samples, one core, free from any obvious fat or connective tissue was chosen for press fluid determinations. All samples were covered with Saran™, and refrigerated ($3^{\circ}\pm1^{\circ}C$) for 1 - 2 h, until 30 min prior to evaluation.

Figure 5. Sampling plan for penetrometer, press fluid, sensory and shear measurements of semitendinosus roasts.



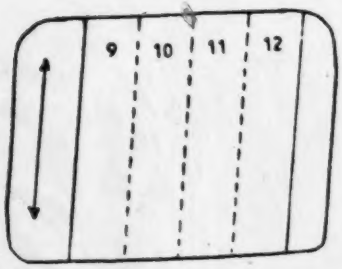
SLICE 1 (1.3 cm thick)

Cores 1 - 3: Penetrometer test
(Core size = 1.3 x 1.3 x 4-5 cm)



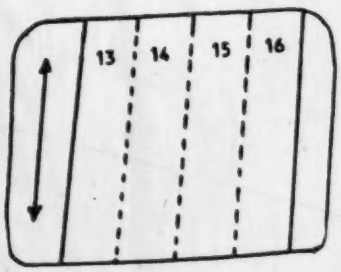
SLICE 2 (1.3 cm thick)

Core 4: Press fluid test
Cores 5 - 8: Sensory test
(cut into 1.3 cm^3)



SLICE 3 (1.3 cm thick)

Cores 9 - 12: Sensory test
(cut into 1.3 cm^3)



SLICE 4 (1.3 cm thick)

Cores 13 - 16: Instron Warner-Bratzler shear test

Objective measurements: Cooked samples

Cooking time and final temperature

The cooking time (min) required for each roast to rise from an internal temperature of 10°C to 65°C was determined. The cooking time of each roast was also calculated in min per 100 g raw weight of the thawed roast. The post-oven temperature rise (final temperature) was recorded to the nearest 0.5°C for each roast.

Cooking losses

The amounts of total, volatile and drip losses were calculated as percentages based on the weight of the thawed roast.

Colour

The colour of each cooked roast was measured using a Hunterlab Color/Difference Meter (Model D25A-2). The meter was standardized daily against a white standard tile (C2-8692) with values of L=92.7, a=-1.0 and b=0.3, and calibrated weekly using a set of coloured tiles. The meter was used in the inverted position and was equipped with the small light exposure port (1.8 cm in diam). Thirty min prior to testing, samples were removed from the refrigerator and equilibrated to room temperature (22°C). The unwrapped meat sample was allowed to bloom for exactly 5 min. To measure the colour, the bloomed surface of the sample was placed directly over the

port, and 'L, a and b' values were recorded. Four readings were obtained on each sample by rotating the sample 90° for each reading.

Penetrometer

Penetrometer readings for each cooked roast were determined following the procedures outlined by Paul et al., (1970). Three cores of beef (22°C) were tested for softness using a penetrometer (Precision Scientific, Model GCA) equipped with a 102.5 g penetration cone. The cone was released for exactly 5 sec and the reading was taken. Two readings were made on each of the cores; therefore, for each roast, an average of six readings was determined.

Press fluid

The percentage press fluid of each cooked roast was determined using the method of Stanley and Swatland (1976). A sample (0.45 - 0.55 g) was cut, perpendicular to the grain, from the core (22°C) using a scalpel and a pair of tweezers to minimize sample handling. Each weighed sample was pressed at a pressure of 880.7 kg/cm^2 for 60 sec, using a Carver Laboratory Press (Fred S. Carver, Inc., Model C). Immediately after, the pressed sample was weighed to determine the weight of the pressed fluid. Press fluid was expressed as a percentage, based on the weight of the original, unpressed meat sample. Triplicate samples were measured for each roast.

Instron Warner-Bratzler shear

Shear determinations were made on four meat cores per cooked roast. An Instron Food Testing System (Model 4201), equipped with a Warner-Bratzler blade attachment and a 50 kg load cell, was used. The travelling speed of the crosshead was set at 150 mm/min. Each core (22°C) was sheared twice perpendicular to the grain, and the peak force required for shearing was recorded. For each roast, an average of the eight shear values was determined.

Subjective measurements: Slice evaluation

During each panel session, five experienced panelists from the staff of the Department of Foods and Nutrition, University of Alberta, independently evaluated the appearance of cooked beef slices in a Macbeth Skylight booth (Model BBX-826, 2 - 1000 watt bulbs). Panelists used a category scale scorecard (Appendix 1) to evaluate the degree of doneness (internal colour) and texture of the randomly presented beef slices. The degree of doneness was scored on a double-pointed category scale (9=rare, 5=medium, 1=well-done). Texture was rated on a five-point scale (5=fine, 1=coarse, stringy).

Subjective measurements: Sensory evaluation

Eight trained panelists evaluated the eating quality of cooked beef from all treatment combinations. The panelists assessed the beef for softness, initial juiciness, juiciness,

flavour (intensity and desirability), tenderness and connective tissue (amount and softness).

Screening of panelists

Panelists were chosen during a preliminary screening of 19 volunteers from the staff and students in the Department of Foods and Nutrition, University of Alberta. A screening procedure similar to that of Cross et al. (1978) was used. The potential panelists completed a series of 15 triangle tests over a four day period. For each triangle test, panelists selected the odd meat sample with respect to tenderness, juiciness or amount of connective tissue, and indicated the degree and direction of difference. Panelists correctly identified the odd sample 67% of the time, with a range of 40 - 78% over all the 15 triangles. Fifteen panelists were selected for training on the basis of their ability to correctly identify the odd sample, interest in the study and availability for the duration of the study.

Training of panelists

Training sessions were conducted three to four times per week for seven weeks. All sessions were held in the sensory panel room in the Department of Foods and Nutrition. During the first week, the panelists were introduced to basic panel procedures, sensory methods and scorecard characteristics. Instruction sheets with definitions for each

of the descriptive attributes were provided (Appendix 2). Panelists evaluated the beef samples for softness, initial juiciness, tenderness and connective tissue (amount and softness) using an 8-point category scale, as described by the American Meat Science Association (1978). A value of '8' represented an extremely soft, juicy, tender sample with no connective tissue; whereas, a value of '1' represented an extremely firm, dry, tough sample with an abundance of firm connective tissue. The scorecard used during this phase of training is illustrated in Appendix 3.

During the second week, raisins (Sunmaid™ dark, seedless) and cubes of mozzarella cheese (Kraft™, 28% fat, 1.3 cm^3) were introduced as anchors for scoring initial juiciness and softness, respectively. Panelists were asked to score the initial juiciness of one raisin and the softness of one cube of cheese using the same scale as that used for evaluating beef. Panelist consensus was reached to designate anchor points for each of the two attributes. During subsequent panel sessions, panelists were given samples of raisins and cheese to help anchor their initial juiciness and softness scores. The emphasis during the third week of training was on juiciness (overall) and flavour (intensity and desirability). Revised instruction sheets with the additional definitions (Appendix 4) and a longer scorecard (Appendix 5) were given to the panelists. A score of '8' represented an extremely juicy sample with an extremely intense or desirable

flavour; and a score of '1' represented an extremely dry sample with an extremely weak or undesirable flavour, as described by AMSA (1978). This scorecard (Appendix 5) was used for the remainder of panel training and for the study.

The panelists were also asked to count the number of chews required to completely masticate each sample. For each panelist, individualized chew cards, matching the number of chews with tenderness scores, were developed. During the fifth week of training, the panelists used their individual chew ranges to evaluate the tenderness of the meat according to the number of chews required for complete mastication.

The sixth and seventh weeks of training concentrated on the evaluation of samples very similar to those to be evaluated during the actual study.

Evaluation of panelist performance

Two panelist performance evaluations were conducted during the third and fifth weeks of training, following the procedure described by Cross et al. (1978). Both evaluations consisted of four replications of six treatments (including a duplicated sample), conducted on four consecutive days. Panelists were judged on their ability to distinguish differences among treatments and to replicate judgements consistently. Based on the data collected for the first evaluation, 11 of the 15 panelists were selected for continued training. The results also provided information regarding the

quality attributes which were difficult for the panelists to assess. Subsequent training sessions focussed on panelist weaknesses. The second evaluation of panelist performance used meat samples similar to those to be evaluated during the study. Data collected in this evaluation confirmed that further training was not necessary. From the results of the second evaluation, eight panelists were selected for the study.

Sample presentation

Panel sessions, each lasting 25 - 30 min, were held in an atmospherically-controlled sensory panel room, equipped with eight individual booths. White lights were used during the evaluations.

Based on the experimental design, during each panel session, each of the eight panelists evaluated beef samples from eight semitendinosus (ST) roasts: four roasts taken from a conventionally chilled side, and subjected to the four different aging periods and four roasts taken from a spray chilled side, and subjected to the four different aging periods. All roasts on a particular day were from one carcass, which was either shrouded or unshrouded. Thus, a total of 16 panel sessions was required for the study.

At each session, panelists were given cubes of beef taken from the same positions in each of the roast slices. The positions were assigned in a rotating order, so that each

panelist received beef cubes from a different relative position in the beef slices at each session.

Each panelist was provided with two cubes of beef from each roast. Thirty min prior to the panel session, the two cubes of beef were placed in a small covered glass jar, labelled with a three-digit random code. All eight jars for each panelist were arranged in a predetermined randomized order. Five min prior to the panel session, the first four samples for each panelist were set in the heating system, and allowed to warm to 50°C. The system was composed of three Corningware™ casserole dishes assembled into a double-boiler arrangement, and heated on a Salton Hotray™. After evaluating the first four beef samples, the panelists left the sensory panel room for 15 min, in which time the the second set of four samples were warmed. Room temperature tap water (22°C), napkins, toothpicks and the raisin/cheese anchors were also provided in each booth, along with the coded scorecards and individual chew range cards.

4 RESULTS AND DISCUSSION

Shrouding

Data for the changes in temperature of the longissimus dorsi (LD) and semimembranosus (SM) muscles during the cooling of shrouded and unshrouded sides are presented in Table 1. Temperature data for the LD and SM muscles were generally not affected by the method of shrouding. At 8 h, the temperature of the SM muscle in unshrouded sides was lower ($P<0.001$) than that in SM muscles from shrouded sides; however, this difference was not apparent in the LD muscle. After 24 h of cooling, the temperature difference due to shrouding treatment for either the LD or SM muscle was not evident. Carcass shrinkage determined after 24 h of cooling, showed that shrouded sides had less ($P<0.05$) shrinkage than unshrouded sides. The values for carcass shrinkage at 24 h for shrouded (0.89%) and unshrouded sides (1.08%) are typical of those obtained in a North American conventional chilling system. Kastner (1981) provided the values of 0.75 - 2.0% as the typical shrinkage amounts to be expected of shrouded beef carcasses chilled overnight under conventional chilling conditions.

Chemical data for semitendinosus (ST) muscles excised from shrouded and unshrouded sides show that only percent moisture was affected by shrouding method (Table 2). Semitendinosus muscles excised from unshrouded sides had significantly higher ($P<0.05$) percent moisture than ST muscles

Table 1. Means and standard errors for changes in muscle temperature and carcass shrinkage in shrouded and unshrouded sides during cooling.

Measurement	Shrouding Treatment		SEM[1]
	Shrouded	Unshrouded	
Temperature[2], °C			
LD[3] at 45 min	39.26	38.97	0.17
SM[4] at 45 min	40.50	40.30	0.19
LD at 4 h	17.05	16.62	0.41
SM at 4 h	32.20	31.62	0.32
LD at 8 h	9.14	8.74	0.35
SM at 8 h	24.03	22.34	0.28***
LD at 24 h	2.66	3.42	0.54
SM at 24 h	8.07	8.20	0.18
Carcass shrinkage[5], %			
At 8 h	0.25	0.33	0.09
At 24 h	0.89	1.08	0.06*

[1]Standard error of the mean.

[2]Values are the means of 16 determinations (1 per muscle of each side).

[3]LD = longissimus dorsi muscle.

[4]SM = semimembranosus muscle.

[5]Values are the means of 16 determinations (1 per side).

*,***Significant at $P<0.05$ and $P<0.001$, respectively.

Table 2. Means and standard errors for chemical determinations for semitendinosus muscles excised from shrouded and unshrouded sides.

Chemical Data[1]	Shrouding Treatment		SEM[2]
	Shrouded	Unshrouded	
pH	5.6	5.6	0.03
Fat, %	1.0	0.8	0.10
Moisture, %	75.3	76.4	0.29*

[1] Values are the means of 32 determinations (2 per muscle).

[2] Standard error of the mean.

*Significant at $P<0.05$.

from shrouded sides. Percentages of moisture for ST muscles excised from steer carcasses, as reported by various researchers (Hawrysh et al., 1975; Hawrysh and Berg, 1976; Hunt and Hedrick, 1977; Hawrysh and Berg, 1979) were notably lower than the value determined for the ST muscle obtained from shrouded sides (76.4%) in the present study. This difference in percent moisture may be attributed to the lower fat content of the ST muscles analyzed in the present study compared to the ST muscles in the earlier research. A trend for decreasing percent moisture with increasing fat content for ST muscles was observed in the data of Hawrysh and Berg (1976). Percent moisture content for beef obtained from unshrouded sides has not been reported in the published literature.

Data showing the influence of shrouding on the colour of ST roasts before and after vacuum-packaged aging are presented in Table 3. Differences in Hunter 'L, a and b' values due to shrouding method were only significant for unaged ST roasts. Prior to aging, roasts obtained from shrouded sides were darker ($P<0.01$), more ($P<0.01$) red and more ($P<0.01$) yellow than comparable unaged roasts from unshrouded sides. Following aging, 'L, a and b' values for roasts from shrouded and unshrouded sides were similar. Published information regarding the effects of shrouding on colour of beef roasts is unavailable.

Table 3. Means and standard errors for colour measurements for semitendinosus roasts obtained from shrouded and unshrouded sides.

Colour Data[1,2]	Shrouding Treatment		SEM[3]
	Shrouded	Unshrouded	
Unaged roasts			
L	31.5	33.5	0.44**
a	6.7	5.5	0.17**
b	4.7	3.9	0.14**
Aged roasts			
L	33.0	33.1	0.48
a	8.8	8.6	0.26
b	6.0	5.6	0.04

[1] Readings were measured using the Macbeth Color Measuring System.

[2] Values are the means of 128 determinations (2 per roast).

[3] Standard error of the mean.

**Significant at $P<0.01$.

Cooking data from ST roasts were generally not affected by shrouding (Table 4). Percent drip loss during cooking was the only parameter significantly affected by shrouding method. Roasts obtained from shrouded sides had higher ($P<0.05$) percent drip loss than the roasts from unshrouded sides. No studies have reported cooking data for roasts obtained from beef sides subjected to shrouding treatments; however, some researchers have determined cooking losses for ST roasts from shrouded carcasses or sides. The values for cooking losses for ST roasts from both shrouded and unshrouded sides determined in the present study are similar to values reported by Hawrysh et al. (1975) and Hawrysh et al. (1979) for conventionally roasted ST roasts (final internal temperature of 65°C) from shrouded carcasses.

Results for subjective measurements of cooked ST roasts obtained from shrouded and unshrouded sides are summarized in Table 5. The judges detected no differences in degree of doneness and texture of the cooked beef slices due to shrouding method. Trained panelists found the cooked samples of ST roasts taken from shrouded and unshrouded sides to be similar in softness, initial juiciness, juiciness, flavour (intensity and desirability) and tenderness. Cooked roasts from unshrouded sides had a smaller ($P<0.05$) amount of and softer ($P<0.05$) connective tissue than comparable roasts from shrouded sides. Reasons for the differences in connective tissue due to shrouding obtained in the present study are not

Table 4. Means and standard errors for cooking data for semitendinosus roasts obtained from shrouded and unshrouded sides.

Cooking Data[1]	Shrouding Treatment		SEM[2]
	Shrouded	Unshrouded	
Raw weight, g	433.9	409.9	18.07
Drip in aging, %	1.7	1.5	0.17
Drip in thaw, %	18.5	17.7	1.41
Final internal temperature, °C	67.2	67.1	0.19
Cooking time, min	58.0	57.3	1.07
Cooking time, min/100g	13.4	14.3	0.51
Cooking losses, %			
Total	21.9	21.6	0.43
Volatile	18.8	19.0	0.34
Drip	3.1	2.6	0.15*

[1]Values are the means of 64 determinations (1 per roast).

[2]Standard error of the mean.

*Significant at $P<0.05$.

Table 5. Means and standard errors for subjective measurements for semitendinosus roasts obtained from shrouded and unshrouded sides.

Measurement	Shrouding Treatment		SEM[1]
	Shrouded	Unshrouded	
Slice evaluation[2]			
Degree of doneness[3]	4.1	4.1	0.13
Texture[4]	3.7	3.9	0.11
Sensory evaluation[5,6]			
Softness	5.3	5.6	0.14
Initial juiciness	5.8	5.9	0.05
Juiciness	5.0	5.0	0.06
Flavour			
- intensity	5.5	5.4	0.04
- desirability	5.2	5.3	0.05
Tenderness	6.1	6.4	0.12
Connective tissue			
- amount	6.6	6.9	0.10*
- softness	6.5	6.9	0.10*

[1] Standard error of the mean.

[2] Values are the means of 320 determinations (5 per roast).

[3] Doneness scale: 1=well-done; 5=medium; 9=rare.

[4] Texture scale: 1=coarse, stringy; 5=fine.

[5] Values are the means of 512 determinations (8 per roast).

[6] Sensory evaluation scale (8-points): Higher values (8) indicate increased softness, initial juiciness, juiciness, flavour (intensity and desirability), tenderness, connective tissue softness and decreased connective tissue amount.

*Significant at $P<0.05$.

readily apparent. However, studies investigating the effects of shrouding on the sensory measurements of cooked beef are lacking.

Data for objective measurements for cooked ST roasts obtained from shrouded and unshrouded sides are given in Table 6. Except for the Hunter 'b' yellowness value, shrouding did not influence objective results. Cooked roasts taken from unshrouded sides were more ($P<0.05$) yellow than comparable roasts from shrouded sides. No reason for this difference is readily apparent and no literature regarding the effect of shrouding on the colour of cooked beef is available.

Spray chilling

At 4 and 8 h, temperatures of both the LD and SM muscles in spray chilled sides (Table 7) were significantly lower than those in comparable conventionally chilled sides; however, this temperature difference due to spray chilling was only found in the SM muscle at 24 h. After both 8 and 24 h of cooling, percent carcass shrinkage values for spray chilled sides were lower ($P<0.001$) than comparable values for conventionally chilled sides.

Chilling method (Table 8) had no significant effect on any of the chemical determinations for ST muscles. Studies on the chemical analysis of beef subjected to spray chilling treatments are lacking.

Unaged raw roasts obtained from conventionally chilled sides had higher ($P<0.05$) 'b' yellowness values than

Table 6. Means and standard errors for objective measurements for semitendinosus roasts obtained from shrouded and unshrouded sides.

Objective Data	Shrouding Treatment		SEM[1]
	Shrouded	Unshrouded	
Hunter colour[2]			
L	49.1	49.2	0.36
a	7.3	8.2	0.46
b	11.6	12.1	0.12*
Penetrometer[3], mm	7.1	7.1	0.20
Instron Warner-Bratzler shear[4], kg	5.2	5.3	0.17
Press fluid[5], %	45.9	45.7	0.31

[1] Standard error of the mean.

[2] Values are the means of 256 determinations (4 per roast).

[3] Values are the means of 384 determinations (6 per roast).

[4] Values are the means of 512 determinations (8 per roast).

[5] Values are the means of 192 determinations (3 per roast).

*Significant at $P<0.05$.

Table 7. Means and standard errors for changes in muscle temperature and carcass shrinkage in conventionally and spray chilled sides during cooling.

Measurement	Chilling Treatment		
	Conventional	Spray	SEM[1]
Temperature[2], °C			
LD[3] at 45 min	39.08	39.14	0.08
SM[4] at 45 min	40.37	40.42	0.05
LD at 4 h	18.02	15.66	0.33***
SM at 4 h	32.72	31.11	0.40*
LD at 8 h	10.40	7.49	0.17***
SM at 8 h	24.56	21.81	0.36***
LD at 24 h	2.79	3.29	0.55
SM at 24 h	8.82	7.44	0.09***
Carcass shrinkage[5], %			
At 8 h	0.95	-0.38[6]	0.07***
At 24 h	1.49	0.48	0.08***

[1] Standard error of the mean.

[2] Values are the means of 16 determinations (1 per muscle of each side).

[3] LD = longissimus dorsi muscle.

[4] SM = semimembranosus muscle.

[5] Values are the means of 16 determinations (1 per side).

[6] A negative value for % carcass shrinkage indicates a gain in side weight.

*,***Significant at $P<0.05$ and $P<0.001$, respectively.

Table 8. Means and standard errors for chemical determinations for semitendinosus muscles excised from conventionally and spray chilled sides.

Chemical Data[1]	Chilling Treatment		
	Conventional	Spray	SEM[2]
pH	5.6	5.6	0.01
Fat, %	1.0	0.8	0.07
Moisture, %	75.9	75.9	0.09

[1] Values are the means of 32 determinations (2 per muscle).

[2] Standard error of the mean.

comparable roasts taken from spray chilled sides (Table 9). Chilling method had no significant effect on either the 'L and a' values of unaged roasts or the 'L' values of aged roasts. However, the 'a and b' values for aged raw roasts obtained from conventionally chilled sides were higher ($P<0.05$) than comparable values for raw roasts from spray chilled sides. Studies reporting Hunter 'L, a and b' values for roasts obtained from beef sides subjected to different chilling methods have not been published. However, Jones and Robertson (1988b) determined C.I.E. (Y, x and y) values for the LD muscle from shrouded and unshrouded beef sides subjected to conventional and spray chilling treatments. They (Jones and Robertson, 1988b) found no changes in the colour values for beef due to chilling method.

Roasts from spray chilled sides (Table 10) required a significantly longer ($P<0.05$) cooking time per 100 g thawed roast weight than comparable roasts from conventionally chilled sides. This difference in cooking time would not be expected considering that the raw weight and final internal temperature for roasts from conventionally and spray chilled sides did not differ significantly.

Generally, chilling methods had no influence on the subjective data (Table 11) obtained for the cooked ST roasts. The only significant difference found was for the flavour intensity. Panelists judged the flavour of the cooked meat from conventionally chilled sides to be more ($P<0.01$) intense

Table 9. Means and standard errors for colour measurements for semitendinosus roasts obtained from conventionally and spray chilled sides.

Colour Data[1,2]	Chilling Treatment		SEM[3]
	Conventional	Spray	
Unaged roasts			
L	32.6	32.5	0.12
a	6.2	5.9	0.09
b	4.4	4.2	0.08*
Aged roasts			
L	33.3	32.9	0.20
a	8.9	8.5	0.09*
b	6.0	5.7	0.08*

[1] Readings were measured using the Macbeth Color Measuring System.

[2] Values are the means of 128 determinations (2 per roast).

[3] Standard error of the mean.

*Significant at $P<0.05$.

Table 10. Means and standard errors for cooking data for semitendinosus roasts obtained from conventionally and spray chilled sides.

Cooking Data[1]	Chilling Treatment		SEM[2]
	Conventional	Spray	
Raw weight, g	422.2	421.5	6.23
Drip in aging, %	1.6	1.6	0.11
Drip in thaw, %	17.6	18.5	0.95
Final internal temperature, °C	67.2	67.1	0.09
Cooking time, min	56.4	58.9	0.89
Cooking time, min/100g	13.5	14.2	0.22*
Cooking losses, %			
Total	21.8	21.7	0.24
Volatile	19.0	18.8	0.20
Drip	2.8	2.9	0.09

[1] Values are the means of 64 determinations (1 per roast).

[2] Standard error of the mean.

*Significant at $P<0.05$.

Table 11. Means and standard errors for subjective measurements for semitendinosus roasts obtained from conventionally and spray chilled sides.

Measurement	Chilling Treatment		
	Conventional	Spray	SEM[1]
Slice evaluation[2]			
Degree of doneness[3]	3.9	4.2	0.12
Texture[4]	3.8	3.8	0.08
Sensory evaluation[5,6]			
Softness	5.4	5.5	0.08
Initial juiciness	5.9	5.8	0.06
Juiciness	5.0	4.9	0.05
Flavour			
- intensity	5.5	5.4	0.04**
- desirability	5.3	5.3	0.04
Tenderness	6.2	6.3	0.07
Connective tissue			
- amount	6.7	6.8	0.06
- softness	6.7	6.7	0.07

[1] Standard error of the mean.

[2] Values are the means of 320 determinations (5 per roast).

[3] Doneness scale: 1=well-done; 5=medium; 9=rare.

[4] Texture scale: 1=coarse, stringy; 5=fine.

[5] Values are the means of 512 determinations (8 per roast).

[6] Sensory evaluation scale (9-points): Higher values (8) indicate increased softness, initial juiciness, juiciness, flavour (intensity and desirability), tenderness, connective tissue softness and decreased connective tissue amount.

**Significant at $P<0.01$.

than that of the cooked roasts from spray chilled sides. Although significant, these small differences in flavour are probably not of practical importance.

Objective data for cooked roasts obtained from conventionally and spray chilled sides (Table 12) showed no significant differences attributable to chilling method. Jones and Robertson (1988b) found no significant difference in the shear values for cores of cooked beef rib steak obtained from conventionally and spray chilled beef sides. However, in evaluating the effects of spray chilling on pork carcasses, Jones et al. (1988) found OTMS Warner-Bratzler shear force values to be higher for meat taken from spray chilled carcasses than for comparable samples from carcasses subjected to conventional chilling.

Interaction effects of shrouding and chilling

No published studies have reported data regarding the individual effects of shrouding or spray chilling on changes in muscle temperature and on carcass shrinkage as in Tables 1 (p.48) and 7 (p.57). Jones and Robertson (1988b) provided data for the combined interaction effects of the shrouding and chilling treatments on parameters similar to those determined in the present study. Table 13 gives data for the shroud by chill interaction effects on muscle temperature and carcass shrinkage arranged in a manner similar to Allen et al.(1987) and Jones and Robertson (1988b). For the interactions which

Table 12. Means and standard errors for objective measurements for semitendinosus roasts obtained from conventionally and spray chilled sides.

Objective Data	Chilling Treatment		
	Conventional	Spray	SEM[1]
Hunter colour[2]			
L	49.2	49.1	0.33
a	7.4	8.0	0.24
b	11.8	11.9	0.07
Penetrometer[3], mm	7.0	7.1	0.12
Instron Warner-Bratzler shear[4], kg	5.3	5.2	0.08
Press fluid[5], %	45.9	45.7	0.31

[1] Standard error of the mean.

[2] Values are the means of 256 determinations (4 per roast).

[3] Values are the means of 384 determinations (6 per roast).

[4] Values are the means of 512 determinations (8 per roast).

[5] Values are the means of 192 determinations (3 per roast).

Table 13. Means and standard errors for changes in muscle temperature and carcass shrinkage for conventionally and spray chilled sides during cooling as influenced by shrouding method.

	Shrouded		Unshrouded		
Measurement	Conv[1]	Spray	Conv	Spray	SEM[2]
Temperature[3], °C					
LD[4] at 45 min	39.21	39.30	38.95	38.99	0.11
SM[5] at 45 min	40.51	40.49	40.23	40.36	0.07
LD at 4 h	17.80	16.30	18.23	15.01	0.46
SM at 4 h	32.97	31.42	32.46	30.79	0.56
LD at 8 h	10.15a	8.14b	10.65A	6.83B	0.24***
SM at 8 h	25.12a	22.94b	23.99A	20.69B	0.51***
LD at 24 h	2.01	3.31	3.57	3.27	0.78
SM at 24 h	8.72	7.41	8.92	7.47	0.13
Carcass shrinkage[6], %					
At 8 h	0.66a	-0.16[7]b	1.24A	-0.59B	0.09**
At 24 h	1.25a	0.53b	1.73A	0.44B	0.11*

[1] Conv = conventional method of chilling.

[2] Standard error of the mean.

[3] Values are the means of 8 determinations (1 per muscle of each side).

[4] LD = longissimus dorsi muscle.

[5] SM = semimembranosus muscle.

[6] Values are the means of 8 determinations (1 per side).

[7] A negative value for % carcass shrinkage indicates a gain in side weight.

[ab] Means within the shrouded treatment sharing a common letter are not significantly different at $P<0.05$.

[AB] Means within the unshrouded treatment sharing a common letter are not significantly different at $P<0.05$.

*,**,***Significant shroud by chill interaction at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

were significant, specific comparisons of interest between cell means were made using Fisher's Protected LSD statistical test (Steel and Torrie, 1980). At 8 h, for shrouded and unshrouded sides, both muscles from spray chilled sides had lower muscle temperatures than comparable muscles from conventionally chilled sides. The muscle temperatures for the LD and SM muscles from unshrouded spray chilled sides were lower ($P<0.05$) than those for the muscles from all other shroud by chill combinations at 8 h. Jones and Robertson (1989) reported lower temperatures for LD and SM muscles in spray chilled (8 h spray period) shrouded and unshrouded sides than in comparable muscles from conventionally chilled sides after 4, 8 and 24 h of cooling. In the present study, the changes in muscle temperature due to chilling method in both shrouded and unshrouded sides were not significant at 24 h.

Significant interaction effects for carcass shrinkage after 8 h and 24 h of cooling appear in Table 13. At 8 h, an increase in side weight for both shrouded and unshrouded spray chilled sides was observed. The spray chilling of shrouded sides caused a 0.16% gain in side weight; whereas, unshrouded sides subjected to the water spray treatment gained even more (0.59%) weight. Although the values for shrouded and unshrouded spray chilled sides at 24 h did not indicate a gain in side weight, these sides had lower ($P<0.05$) shrinkage values than their conventionally chilled counterparts. Jones and Robertson (1988b) reported similar findings for carcass

shrinkage of shrouded and unshrouded beef sides exposed to 8 h of water spray chilling. After 8 h of cooling, spray chilled shrouded and unshrouded beef sides gained weight (0.18% and 0.72%, respectively); and after 24 h of cooling, spray chilled shrouded and unshrouded sides had carcass shrink values of 0.60% and 0.35%, respectively (Jones and Robertson, 1988b). The carcass shrink values for conventionally chilled beef sides in the present study were very similar to those found in the study by Jones and Robertson (1988b).

At 24 h, percent carcass shrinkage was lowest ($P<0.05$) for unshrouded, spray chilled sides (Table 13, p.65). This finding agrees with the results of Jones and Robertson (1988b). Concerning the percent carcass shrinkage data (Table 13, p.65), some interesting observations of economical impact may be made. Unshrouded, spray chilled sides had a shrinkage value of 0.44%; whereas unshrouded conventionally chilled sides had a shrinkage value of 1.73%. The low shrinkage value for the unshrouded, spray chilled sides would result in a saving of 1.29% in side weight compared to the conventionally chilled counterparts. A difference in carcass shrinkage of this magnitude may provide economical savings of commercial value (Hamby et al., 1987).

Vacuum-packaged postmortem aging time

Means and standard errors for 'L, a and b' values for unaged ST roasts and roasts aged in vacuum-packaging for 3,

10, 24 or 38 d are shown in Table 14. Hunter 'L, a and b' values for roasts prior to vacuum-packaged aging for the assigned time period appear in parentheses. The initial 'L, a and b' values for roasts prior to vacuum-packaging were not significantly different. However, after the assigned aging period, the ST roasts aged for the shortest time period (3 d) had the lowest 'L, a and b' values. Roasts aged for 10, 24 and 38 d had similar 'L' values, but the 'L' values were higher ($P<0.01$) than the comparable value for roasts aged for only 3 d. The 'a' redness values for roasts aged for 3, 10, 24 and 38 d were all significantly different, with roasts aged for 10 d having the highest 'a' value. The 'b' yellowness values of roasts aged for 3, 10 and 24 d differed significantly, but roasts aged for 38 d had 'b' values similar to roasts aged for 10 and 24 d. Studies of the consequences of vacuum-packaged aging on the colour of beef roasts obtained from sides subjected to shrouding and chilling treatments are lacking.

Table 15 presents the cooking data for vacuum-packaged ST roasts aged for varying periods of time. Roasts aged for 38 d had significantly higher ($P<0.01$) drip in aging losses than comparable roasts aged for 3 and 10 d. The percent drip in aging for roasts aged for 24 d was similar to the value obtained for roasts aged for 10 and 38 d. Increased drip loss for roasts with increased aging time is generally expected.

Table 14. Means and standard errors for colour measurements for semitendinosus roasts before and after aging in vacuum-packaging for varying periods of time.

Colour data[1,2]	Postmortem Aging Periods (d)				
	3	10	24	38	SEM[3]
L	32.2b (32.8)[4]	33.4a (32.5)	33.2a (32.3)	33.6a (32.6)	0.29** (0.17)
a	7.7d (6.3)	9.5a (6.0)	9.0b (6.0)	8.6c (6.0)	0.13** (0.13)
b	5.2c (4.4)	5.7b (4.2)	6.3a (4.1)	6.0ab (4.5)	0.12** (0.12)

[1]Readings were obtained using the Macbeth Color Measuring System.

[2]Values are the means of 64 determinations (2 per roast).

[3]Standard error of the mean.

[4]Values in parentheses are means for colour measurements for semitendinosus roasts before aging in vacuum-packaging.

[abc]Means within the same row sharing a common letter are not significantly different at $P<0.05$.

**Significant at $P<0.01$.

Table 15. Means and standard errors for cooking data for semitendinosus roasts aged in vacuum-packaging for varying periods of time.

Cooking Data[1]	Postmortem Aging Periods (d)				SEM[2]
	3	10	24	38	
Raw weight, g	428.8	419.8	414.5	424.5	8.79
Drip in aging, %	0.9c	1.6b	1.8ab	2.1a	0.15**
Drip in thaw, %	19.1	19.1	18.0	16.1	1.34
Final internal temperature, °C	67.1	67.2	67.1	67.3	0.12
Cooking time, min	56.2	58.6	57.5	58.2	1.26
Cooking time, min/100g	13.4	14.2	14.1	13.9	0.31
Cooking losses, %					
Total	21.9	22.4	21.2	21.6	0.34
Volatile	18.9	19.3	18.6	18.9	0.28
Drip	3.0	3.1	2.7	2.7	0.13

[1]Values are the means of 32 determinations (1 per roast).

[2]Standard error of the mean.

[abc]Means within the same row sharing a common letter are not significantly different at $P<0.05$.

**Significant at $P<0.01$.

However, Minks and Stringer (1972) found no difference in driploss for beef aged in vacuum-packaging for 7 and 15 d.

Several researchers have monitored percent drip (or purge) losses for vacuum-packaged aged beef obtained from spray chilled sides. A study by Hamby et al. (1987) involved the vacuum-packaging of subprimal cuts of beef from sides subjected to conventional chilling and either intermittent water or organic spray chilling systems. After 28 d of vacuum-packaged aging at 2°C, Hamby et al. (1987) reported slightly higher percent drip in aging values for subprimals from sides treated with water or acid sprays than for the comparable conventionally chilled controls. Allen et al. (1987) monitored drip in aging losses of vacuum-packaged (15 d) ribs and inside rounds from conventionally and spray chilled sides. They (Allen et al., 1987) indicated that drip in aging values were lower for vacuum-packaged beef cuts obtained from conventionally chilled sides than for the comparable spray chilled counterparts; however, these differences were only significant ($P<0.05$) for the inside rounds. The differences between the drip in aging values of the two primal cuts were attributed to the location of the cuts on the beef side. The rounds, located closer to the periphery of the side than the ribs, are more likely to gain more moisture during the water spray treatment; thus, higher drip values during vacuum-packaged aging for rounds than for ribs may be expected (Allen et al., 1987). In contrast, Jones

and Robertson (1988b) found no differences in drip losses after vacuum-packaged aging (6 d) for beef ribs and inside round cuts obtained from conventionally and spray chilled (8 h) sides. In the present study, no differences in drip losses of roasts taken from conventionally and spray chilled sides were found (Table 10, p.61). However, as vacuum-packaged aging time increased, percent drip losses increased (Table 15, p.70). There are no studies comparing the effects of different vacuum-packaged aging periods on the quality of beef obtained from spray chilled sides.

Length of vacuum-packaged aging of roasts had no effect on the visual attributes of the cooked beef slices (Table 16). Trained panelists noted that cooked samples from vacuum-packaged roasts aged for 24 and 38 d were similar and significantly ($P<0.01$) softer than samples from comparable roasts aged for 3 and 10 d, which were similar. The tenderness of cooked ST roasts aged for 24 and 38 d was similar and significantly ($P<0.01$) higher than that of roasts aged for 3 d; but, roasts aged for 10 d did not differ in tenderness from roasts representing each of the other aging periods. For the other subjective measurements, trained panelists found no differences in the cooked ST roasts attributable to aging time.

Because tenderness is considered to be the most important textural property of meat (Szczesniak and Torgeson, 1965), it is interesting to note that the cooked ST roasts taken from

Table 16. Means and standard errors for subjective measurements for semitendinosus roasts aged in vacuum-packaging for varying periods of time.

Measurement	Postmortem Aging Periods (d)				SEM[1]
	3	10	24	38	
Slice evaluation[2]					
Degree of doneness[3]	3.8	4.3	3.9	4.3	0.16
Texture[4]	3.7	3.8	3.7	3.9	0.11
Sensory evaluation[5,6]					
Softness	5.1b	5.2b	5.7a	5.8a	0.12**
Initial juiciness	5.9	5.7	6.0	5.8	0.09
Juiciness	4.9	4.9	5.1	5.0	0.07
Flavour					
- intensity	5.5	5.5	5.4	5.5	0.05
- desirability	5.3	5.3	5.3	5.2	0.05
Tenderness	6.0b	6.1ab	6.4a	6.4a	0.10**
Connective tissue					
- amount	6.7	6.7	6.8	6.8	0.08
- softness	6.6	6.6	6.7	6.8	0.10

[1]Standard error of the mean.

[2]Values are the means of 160 determinations (5 per roast).

[3]Doneness scale: 1=well-done, stringy; 5=medium; 9=rare.

[4]Texture scale: 1=coarse, stringy; 5=fine.

[5]Values are the means of 256 determinations (8 per roast).

[6]Sensory evaluation scale (8-points): Higher values (8) indicate increased softness, initial juiciness, juiciness, flavour (intensity and desirability), tenderness, connective tissue softness and decreased connective tissue amount.

[ab]Means within the same row sharing a common letter are not significantly different at $P<0.05$.

**Significant at $P<0.01$.

sides subjected to the processing treatments examined in this study were rated, on average, as a '6' on the 8-point category scale. A score of '6' is described as "moderately tender" (AMSA, 1978).

No studies in the literature have examined the effects of either shrouding or spray chilling on the palatability of beef aged in vacuum-packaging. However, research on the tenderness-related aging effects of vacuum-packaged, conventionally processed beef, aged at different temperatures for varying periods of time has been reported. Optimal aging times for conventionally processed, vacuum-packaged beef have been recommended as 10 d at 1-2°C (Swatland, 1982), 11 d at 1±1°C (Smith et al., 1978) and 14 d at 2±1°C (Hodges et al., 1974). In the present study, the optimal aging time for ST roasts obtained from beef sides subjected to the treatments of shrouding and spray chilling appears to be similar to the recommended aging times for conventionally processed beef reported in the earlier research.

Means and standard errors for objective measurements for vacuum-packaged ST roasts aged for varying periods of time appear in Table 17. The cooked beef slices from vacuum-packaged roasts aged for 3, 10 and 24 d had similar but higher ($P<0.01$) Hunter 'L' values (lighter) than cooked meat from roasts aged for the longest time period (38 d). However, panelists evaluating the visual appearance of the cooked beef slices detected no difference in degree of doneness (colour)

Table 17. Means and standard errors for objective measurements for semitendinosus roasts aged in vacuum-packaging for varying periods of time.

Objective Data	Postmortem Aging Period (d) 3	10	24	38	SEM[1]
Hunter colour[2]					
L	49.9a	49.4a	49.6a	47.7b	0.46**
a	7.8	7.8	7.4	7.9	0.34
b	12.0	11.9	11.7	11.8	0.10
Penetrometer[3], mm	7.0	7.1	7.0	7.2	0.17
Instron Warner-Bratzler shear[4], kg	5.7a	5.3b	5.0b	5.0b	0.12**
Press fluid[5], %	46.1	45.0	45.7	46.5	0.43

[1]Standard error of the mean.

[2]Values are the means of 128 determinations (4 per roast).

[3]Values are the means of 192 determinations (6 per roast).

[4]Values are the means of 256 determinations (8 per roast).

[5]Values are the means of 96 determinations (3 per roast).

[ab] Means within the same row sharing a common letter are not significantly different at $P<0.05$.

**Significant at $P<0.01$.

attributable to aging time (Table 16, p.73). Although raw vacuum-packaged roasts aged for 3 d had lower ($P<0.01$) 'L' values than comparable roasts aged for longer periods of time, this difference was not found in the Hunter colour data for cooked samples. No published data are available to support these results for the colour of the cooked roasts. Penetrometer measurements for cooked ST roasts aged for 3, 10, 24 and 38 d were not significantly different. Penetrometer readings have been correlated with the sensory attribute of softness, assessed by trained panelists. However, in the present study, the penetrometer data do not support the sensory results. Panelists evaluated roasts aged for 24 and 38 d to be similar and softer ($P<0.01$) than roasts aged for 3 and 10 d (Table 16, p.73), which were judged to be of the same softness. Instron Warner-Bratzler shear determinations indicated that the force required to shear cooked beef samples aged for 10 d or longer was less ($P<0.01$) than that needed to shear comparable beef aged for 3 d. These shear data generally support the panelists' sensory ratings for tenderness, which indicated that roasts aged 24 and 38 d were more tender than roasts aged for 3 d (Table 16, p.73). Vacuum-packaged aging time did not affect press fluid data of cooked ST roasts. These press fluid results are in agreement with the sensory scores of the trained panel for initial juiciness (Table 16, p.73).

Limited research investigating the eating quality of beef subjected to the treatments examined in this study has been

reported in the literature. More studies involving sensory and objective measurements of beef subjected to shrouding, spray chilling and vacuum-packaged aging treatments are required. Research is needed to ensure that these treatments for processing beef will provide the consumer with meat of optimal quality.

Correlations between subjective and objective measurements

Generally, the objective data for Hunter colour, penetrometer, Instron Warner-Bratzler shear and press fluid measurements for cooked ST roasts support the trained panelists' scores for degree of doneness, softness, tenderness and juiciness, respectively. Table 18 presents the Pearson correlation coefficients assessing the relationships between subjective and objective measurements for tenderness and juiciness of cooked ST roasts from the shrouding, chilling and postmortem vacuum-packaged aging treatments. Correlations for Instron Warner-Bratzler shear and penetrometer data with sensory scores were all significant. For press fluid measurements, only the correlation coefficients between this measurement and each of the sensory measurements for softness, initial juiciness, juiciness and tenderness were significant.

Leporiere (1976) classified correlation coefficients (r) greater than 0.76 to be "excellent". Correlation coefficients (r) were described as "good" if r is between 0.51 and 0.75;

Table 18. Pearson correlation coefficients (r) between sensory and objective measurements for tenderness and juiciness scores for semitendinosus roasts.

	Objective Measurements		
Sensory Measurements	Instron Warner-Bratzler shear	Penetrometer	Press Fluid
Softness	-0.67***	0.23***	0.20**
Initial juiciness	-0.30***	0.35***	0.38***
Juiciness	-0.33***	0.36***	0.30***
Tenderness	-0.64***	0.32***	0.16*
Connective tissue			
- amount	-0.37***	0.17*	0.09
- softness	-0.40***	0.23**	0.14

*,**,***Significant at $P<0.05$, $P<0.01$ and $P<0.001$, respectively.

"fine" if r is between 0.26 and 0.50; and no correlation is shown if r is between 0.01 and 0.25, irrespective of the sign (Leporiere, 1976). The correlation coefficients for shear data with softness and tenderness scores were -0.67 and 0.64, respectively. According to Leporiere (1976), correlation coefficients of this magnitude can be considered as "good". Correlation coefficients for initial juiciness and juiciness with the three objective measurements were low. Low correlation coefficients may be expected if the range of differences for a particular parameter is small (Cross et al., 1978). In the present study, trained panelists found no significant difference in either initial juiciness or juiciness attributable to any of the experimental treatments (Table 5, p.54, Table 11, p.62, Table 16, p.73). Connective tissue amount and softness were more highly correlated with Instron Warner-Bratzler shear measurements than with penetrometer data, but these correlations can only be considered as "fine". Cross et al. (1973) reported some significant correlations between Warner-Bratzler shear force values and connective tissue amount in beef samples. Researchers (Cover et al., 1962a; Bouton and Harris, 1972a; Cross et al., 1973) have suggested that shear force values correlate more highly with muscle fiber properties than with connective tissue characteristics in cooked muscle. In the present study, Instron Warner-Bratzler measurements were more closely related to tenderness scores than to the connective tissue components determined by trained panelists.

5 SUMMARY AND CONCLUSIONS

The effects of shrouding, spray chilling and postmortem, vacuum-packaged aging time on the quality attributes of ST roasts were evaluated using sensory, instrumental and chemical measurements. Beef sides were either shrouded or unshrouded, and subsequently either conventionally air or water spray chilled. At 24 h, the ST muscle was excised from each side and cut into four roasts. Roasts were individually vacuum-packaged, aged for either 3, 10, 24 or 38 d, and then frozen for later evaluation. Prior to subjective and objective evaluations, thawed roasts were individually roasted at 163°C to an internal temperature of 65°C. At each sensory panel session, trained panelists assessed the quality attributes of warm samples from eight cooked ST roasts taken from a pair of muscles, excised from conventionally and spray chilled sides. Objective measurements on cooked roasts included Hunter 'L, a and b' readings, penetrometer, press fluid and Instron Warner-Bratzler shear (peak force) determinations.

Shrouding method had little influence on muscle temperature or carcass shrinkage during cooling. No differences due to shrouding were found for the percentage fat and pH values of ST muscles. But, ST muscles excised from shrouded sides had significantly lower ($P<0.05$) percent moisture than comparable muscles from unshrouded sides. The colour of raw roasts from shrouded sides, prior to vacuum-packaging for aging, was darker ($P<0.01$), more ($P<0.01$) red

and more ($P<0.01$) yellow than that of comparable roasts from unshrouded sides. After aging, shrouding method had no effect on 'L, a and b' values of raw roasts. Cooking data for ST roasts were generally similar for roasts from sides subjected to either shrouding treatment. However during cooking, roasts from shrouded sides had higher ($P<0.05$) drip losses than comparable roasts from unshrouded sides. Judges detected no differences in degree of doneness and texture of cooked beef slices due to shrouding. Cooked roasts from unshrouded sides had a smaller ($P<0.05$) amount of and softer ($P<0.05$) connective tissue than comparable roasts from shrouded sides. All other sensory characteristics for cooked roasts from shrouded or unshrouded sides were similar. Except for the Hunter 'b' yellowness value which was significantly higher ($P<0.05$) for roasts from unshrouded sides than for roasts from shrouded sides, objective measurements of cooked ST samples showed no differences attributable to shrouding method. The elimination of the shrouding process does not appear to adversely effect the eating quality of beef.

Spray chilling of sides resulted in significant decreases in muscle temperatures and percent carcass shrinkage. However, chilling method did not influence any of the chemical analyses of ST muscles. Unaged roasts from conventionally chilled sides were more ($P<0.05$) yellow than comparable roasts from spray chilled sides, but 'L and a' values were unaffected by chilling method. Aged raw roasts from conventionally

chilled sides were more ($P<0.05$) red and more ($P<0.05$) yellow than comparable roasts from spray chilled sides. However, chilling method did not affect the 'L' lightness value of the aged roasts. No differences in cooking data due to chilling method were found. The degree of doneness and texture of cooked beef slices from roasts representing both chilling methods were similar. Except for flavour intensity, chilling method had no effect on the sensory characteristics of cooked beef samples. Although the flavour of cooked ST roasts from conventionally chilled sides was rated as more intense than the flavour of comparable roasts from spray chilled sides, this difference is probably not of practical importance. Objective data for cooked roasts obtained from both conventionally and spray chilled sides were similar. The use of spray chilling for the processing of beef sides effectively reduced carcass shrinkage and provided for palatable meat.

Data for shroud by chill interactions indicated that spray chilling of shrouded and unshrouded sides was most effective in lowering muscle temperature after 8 h of carcass cooling. Furthermore, spray chilling decreased carcass shrinkage in both shrouded and unshrouded sides. After 8 h of cooling, shrouded and unshrouded spray chilled sides gained weight, suggesting that the sides retained some of the spray water. At 24 h, unshrouded spray chilled sides had the least amount of percent carcass shrinkage.

Results for the cooked ST roasts aged in vacuum-packaging showed that aging time had only a few significant effects on subjective measurements. Initial Hunter 'L, a and b' values for all raw ST roasts prior to vacuum-packaged aging were similar. However, roasts aged for 3 d were darker ($P<0.01$), less ($P<0.01$) red and less ($P<0.01$) yellow in colour than comparable roasts aged for each of the other aging periods. Roasts aged for 10, 24 and 38 d had similar 'L' values. The 'a' redness value of ST roasts differed for all aging times; roasts aged for 10 d were most red. The 'b' yellowness value of roasts aged for 38 d was similar to that of roasts aged for 10 and 24 d. Conclusions regarding these differences in instrumental colour for raw aged ST roasts cannot be made. Meat colour is an important factor influencing consumer acceptance of beef. Thus, to determine if the colour changes in roasts, due to the vacuum-packaged aging time in the present study, are of practical importance, subjective assessments of the colour of the roasts are also required.

Vacuum-packaged aging time had a significant effect on percent drip in aging losses of ST roasts. Roasts aged for 38 d had a higher ($P<0.01$) amount of drip than comparable roasts aged for 3 and 10 d. The percent drip in aging for roasts aged for 24 d was similar to that of roasts aged for 10 and 38 d. All other cooking data were unaffected by aging time. Degree of doneness, texture, initial juiciness, juiciness, flavour (intensity and desirability) and connective

tissue (amount and softness) of cooked roasts were not influenced by the length of vacuum-packaged aging. However, vacuum-packaged aging time affected the softness and tenderness of cooked ST roasts. Roasts aged for 24 and 38 d were similar in softness and significantly ($P<0.01$) softer than comparable cooked roasts aged for 3 and 10 d, which were similar. The tenderness of roasts aged for 24 and 38 d was similar and significantly ($P<0.01$) higher than that of roasts aged for 3 d. But roasts aged for 10 d were similar in tenderness to roasts from the other aging times. Hunter 'a and b' values, penetrometer and press fluid data did not differ for cooked roasts representing each of the aging periods. However, samples from cooked roasts aged for 38 d were darker ($P<0.01$) than comparable samples from roasts aged for 3, 10 and 24 d. This difference in colour was not detected by judges evaluating the degree of doneness in cooked beef slices. Shear data indicated that the force required to shear cooked samples of beef from roasts aged for 10 d or longer was less ($P<0.01$) than that needed to shear the samples from beef roasts aged for 3 d. Shear measurements generally support the sensory scores for meat tenderness suggesting that cooked ST roasts may require more than 10 d of postmortem vacuum-packaged aging for desirable tenderness. Further research involving additional aging periods between 10 and 24 d may provide an indication of the optimal vacuum-packaged

aging time required for beef subjected to the shrouding and chilling treatments investigated in this study.

Spray chilling of both shrouded and unshrouded sides was effective in reducing carcass shrinkage. Data for the interaction between shrouding and chilling treatments indicated that the spray chilling of unshrouded sides resulted in the highest carcass yield after 24 h of postmortem cooling. Thus, shrouding sides before cooling to decrease carcass shrinkage may not be necessary if spray chilling is implemented for cooling unshrouded sides. The combined procedures of unshrouding and spray chilling beef carcasses or sides would be economically beneficial to the meat industry as the costs involved in applying, removing and maintaining the shrouding material would be eliminated and carcass yields would be maximized. Furthermore, both the conventional and spray chilling methods of cooling sides showed no adverse effects on beef palatability.

To ensure provision of beef of optimal quality for consumers, further research examining variations in the spray chilling procedures for unshrouded carcasses is required. The combined effects of different spray water temperatures and spray period durations on beef eating quality require investigation. In order to monitor the possible occurrence of cold shortening in rapidly chilled carcasses, evaluations of muscle fiber characteristics should be conducted if spray water colder than 10°C is employed. Determinations of muscle

pH during carcass cooling should also be included in the experimental procedures of such research. Data on muscle fiber characteristics and pH may be useful in standardizing the optimal length of time for spray chilling beef sides. Spray chilled sides may achieve complete rigor earlier than the usual 24 h period allowed for conventionally chilled sides. Early completion of rigor by spray chilling beef sides would reduce cooler holding time and further maximize cost efficiency in beef production. Moreover, all procedures involved in the implementation of an effective spray chilling system must be standardized to ensure the production of high quality beef.

Because the beef sides retained some of the spray water after 8 h of spray chilling, eating quality evaluations of a muscle closer to the carcass surface (such as the semimembranosus muscle) than the ST muscle may be warranted. Since the spray chilled sides did not show a gain in side weight at 24 h, the extra moisture uptake on spray chilled beef sides at 8 h may not significantly affect the eating quality of muscles closer to the carcass surface. Nevertheless, such research may be appropriate to ensure provision of palatable beef from spray chilled sides for the consumer.

Trained panel evaluations of cooked beef roasts indicated an improvement in meat softness after 24 d of vacuum-packaged aging. Sensory scores for cooked beef tenderness as well as shear determinations showed an increase in tenderness between

10 and 24 d of aging. Results suggest that beef from both conventional and spray chilled sides may be aged in vacuum-packaging for extended periods of time to enhance beef eating quality. However, additional research on the vacuum-packaged aging of beef from unshrouded spray chilled sides is necessary in order to identify the length of vacuum-packaged aging required for optimal cooked beef tenderness and palatability. Beef from unshrouded spray chilled sides should be subjectively evaluated for appearance, both while contained in its vacuum-packaging and following the removal from the packaging, immediately after the aging period. Furthermore, the appearance of beef cuts taken from spray chilled sides, aged in vacuum-packaging and then wrapped in traditional retail packaging (oxygen-permeable) should be assessed, since a large volume of spray chilled beef is merchandised in this manner. In making purchasing decisions, consumers initially assess raw meat quality on the basis of appearance characteristics such as colour and drip losses. No research on the appearance of raw meat from unshrouded spray chilled beef which has been vacuum-packaged and aged for varying lengths of time is available.

Beef ST roasts subjected to the treatments of shrouding, spray chilling and postmortem vacuum-packaged aging time appear to be of desirable eating quality. Standardization of procedures and further research on these processing methods are required to ensure that beef processors continue to provide consumers with quality beef.

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APPENDIX

Appendix 1. Scorecard used for slice evaluation of beef.

Name: _____

Date: _____

SLICE EVALUATION OF BEEF

Sample #: _____

	5	4	3	2	1
Degree of Doneness	Medium				Well-done
					Rare
Texture	Fine	Good	Fair	Slightly coarse	Coarse, stringy

Comments:

Appendix 2. Instruction sheet used during the first two weeks of training.

DEFINITIONS AND TASTING PROCEDURE FOR THE SENSORY EVALUATION OF BEEF

Please rinse your mouth with water before beginning and between samples. Evaluate each beef sample in the order as indicated by your scorecards.

Using a toothpick, place one cube of beef in your mouth between your molar teeth, biting across the grain. Circle a description along the 8-point scale that best describes your impression of each of the characteristics.

SOFTNESS: the amount of force required to bite through a cube of beef across the grain, between the molar teeth. Evaluate the softness after 2 chews.

INITIAL JUICINESS: the amount of moisture in your mouth after 5 chews between the molar teeth.

TENDERNESS: the amount of effort required to completely masticate a cube of beef across the grain. Record the number of chews required for complete mastication. (Note: this does not mean that you chew the sample just until you can swallow it comfortably.)

CONNECTIVE TISSUE AMOUNT: the amount of residue remaining after complete mastication.

CONNECTIVE TISSUE SOFTNESS: the amount of force required to break down the connective tissue.

Appendix 3. Scorecard used for sensory evaluation of beef during the first two weeks of training.

Sensory Evaluation of Beef

Name: _____

Sample #: _____

Date: _____

		8	7	6	5	4	3	2	1
Softness (initial tenderness to 2 chews)		extremely soft	very soft	moderately soft	slightly soft	slightly firm	moderately firm	very firm	extremely firm
Initial Juiciness (5 chews)		extremely juicy	very juicy	moderately juicy	slightly juicy	slightly dry	moderately dry	very dry	extremely dry
Tenderness	# of chews								
		extremely tender	very tender	moderately tender	slightly tender	slightly tough	moderately tough	very tough	extremely tough
Connective Tissue	Amount	no CT	very tiny	tiny	small	slightly large	moderately large	very large	extremely large
	Softness	no CT	very soft	moderately soft	slightly soft	slightly firm	moderately firm	very firm	extremely firm

Comments:

Appendix 4. Instruction sheet used during the last phase of training and for the study period.

TASTING PROCEDURES AND DEFINITIONS
FOR THE
SENSORY EVALUATION OF BEEF

Please rinse your mouth with water before beginning and between samples. Evaluate each beef sample in the order as indicated by your scorecards.

Using a toothpick, place one cube of beef in your mouth between your molar teeth, biting across the grain. Circle a description along the 8-point scale that best describes your impression of each of the characteristics.

SOFTNESS: the amount of force required to bite through a cube of beef across the grain, between the molar teeth. Evaluate softness after 2 chews. Compare with the cheese anchor.

INITIAL JUICINESS: the amount of moisture in your mouth after 5 chews between the molar teeth. Compare with the raisin anchor.

JUICINESS: the amount of moisture in your mouth after complete mastication.

FLAVOUR INTENSITY: the intensity of flavour in your mouth after complete mastication.

FLAVOUR DESIRABILITY: the desirability of the flavour in your mouth after complete mastication.

TENDERNESS: the amount of effort required to completely masticate a cube of beef. Record the number of chews that is required for complete mastication. Check "chew range card".

CONNECTIVE TISSUE AMOUNT: the amount of residue remaining after complete mastication.

CONNECTIVE TISSUE SOFTNESS: the amount of force required to break down the connective tissue.

Appendix 5. Scorecard used during the last phase of training and for the study period.

Sensory Evaluation of Beef

Name: _____

Sample #: _____ Date: _____

		8	7	6	5	4	3	2	1
Softness (initial tenderness to 2 chews)		extremely soft	very soft	moderately soft	slightly soft	slightly firm	moderately firm	very firm	extremely firm
Initial Juiciness (5 chews)		extremely juicy	very juicy	moderately juicy	slightly juicy	slightly dry	moderately dry	very dry	extremely dry
Juiciness		extremely juicy	very juicy	moderately juicy	slightly juicy	slightly dry	moderately dry	very dry	extremely dry
Flavour	Intensity	extremely intense	very intense	moderately intense	slightly intense	slightly weak	moderately weak	very weak	extremely weak
	Desirability	extremely desirable	very desirable	moderately desirable	slightly desirable	slightly undesirable	moderately undesirable	very undesirable	extremely undesirable
Tenderness	# of chews								
		extremely tender	very tender	moderately tender	slightly tender	slightly tough	moderately tough	very tough	extremely tough
Connective Tissue	Amount	no CT	very tiny	tiny	small	slightly large	moderately large	very large	extremely large
	Softness	no CT	very soft	moderately soft	slightly soft	slightly firm	moderately firm	very firm	extremely firm

Comments: